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TRUMP CARD

At the end of last month the Federation of British Industries issued an economic report which examined the causes of post-war financial crises and proposed a number of measures aimed at erecting the " framework of stable money and freedom for enterprise which prosperity requires." The report underlines the difficulty which besets those who would advise the Government on the timing of economic measures to control the trade cycle. It points out that the recent stability in the economic system has been secured largely by cutting down capital investment in the private sector. No one will disagree with this diagnosis; its implications are serious. There is no doubt that such a policy means stagnation and ultimate economic death. The Federation comes out firmly in favour of stimulating new investment as soon as cuts in Government expenditure have been made. In other words, it assumes that such cuts are coming (defence being the obvious candidate) but it does not want to see a revival in investment delayed until these cuts become effective. It looks for a relaxation of investment controls this spring rather than next autumn.

With the economic policy that has been adopted, Britain has required a large balance of payments surplus. The Treasury has put the country's need as an excess of current earnings over current payments of between £300 and £350 million in an average year. This sum is required to meet repayments on loans from the United States and Canada, and to reduce the sterling indebtedness to other countries, including the country's accumulated debit in the European Payments Union, standing at £126 million at the end of January last. Turning from the demands arising from past activities, the financing of commercial activities and other investment in the Commonwealth and elsewhere has to come in part from this same surplus; and the need for long-term capital overseas is growing rather than diminishing. Anything then remaining is available for rebuilding the country's reserves.

In 1956, according to the Treasury's *Bulletin for Industry*, Britain succeeded in changing her balance of payments from a deficit in 1955 to a substantial surplus—thought not, it is admitted, to the £300 million or so that is desired. Part of this change-about was induced by improvements in exports; part is explained by the fact that imports rose hardly at all. That imports did not rise, explains the *Bulletin*, was mainly because industrial production did not rise either. The F.B.I. report tactfully acknowledges that our economic achievements have been impressive, but points out that they have not matched our needs. Neither Britain nor the sterling area as a whole has succeeded in consistently selling abroad enough to pay for imports and to meet essential commitments. To reduce the deficit in balance of payments we have maintained rigid monetary controls. Though difficulties were alleviated by the dollar loans and, later, by the broadening opportunities for trading that the expanding world economy gave, the F.B.I. report observes that it was in external fields that the short-comings of the country's economic record have had their most dangerous consequences. Britain's persistent balance of payments difficulties and crises have been a reflection of collective decisions to enjoy more than has been produced. The post-war inflation was a symptom of the tendency for demand to outrun supply, for too much money to chase too few goods. The result has been that in the last nine years the internal value of the pound has fallen by a third. By stimulating imports and retarding exports, inflation caused recurrent difficulties in the balance of payments, so industrial capital investment was cut back until the outwardly satisfactory state of a more stable economy was achieved.

What then are the remedies? Restoration of the investment allowances to industry and the relaxation of some aspects of the investment squeeze are recommended to the Chancellor at Budget time. The Federation is anxious to bring about certain basic changes in taxation but appreciates that these may have to wait for the cuts in Government expenditure to become effective. Meanwhile, it favours an incentive Budget with maximum emphasis on the encouragement of voluntary private saving to swing the trade cycle upward. This is the critical issue. The internal situation may demand a relaxation of the credit squeeze but this may be taking a big risk with the balance of payments. The report clearly prefers on this occasion to favour the home market and take the risk on the export situation.

But is the risk so large? The volume of exports rose in 1956 by 6 per cent. Despite the obvious difficulties of exporting to parts of the Middle East, there is no sign that the rate of export growth is slackening. The prospects in the dollar area are good, as also in parts of Western Europe. Several substantial contracts of over a million pounds a piece have been notched in the last two months on the capital goods side of the engineering industry. The " three wise men" from Euratom have seen our nuclear engineering groups and have expressed themselves interested in placing contracts here. Our achievements have given us a standard of living such as we—or anyone else, save

the United States—have never experienced before. Boldness should be the watchword. An undeniable lead in contemporary engineering developments is our trump card.

Britain's Economic Problems and Policies, Federation of British Industries. [3s.]

* * *

Plain Words

The annual dinner of the Institution of Electrical Engineers, held in London last Friday, was one of the most successful and enjoyable events of its kind which it has been our good fortune to attend. There were 1,494 other guests and members who must surely have felt as we did. The tone of the evening was established by the President, Sir Gordon Radley, when he announced that the dinner was being held on the 99th birthday of Sir James Swinburne who had occupied the presidential chair no less than 55 years ago. Sir Gordon sought permission of the assembled company to send a congratulatory telegram to their past-President, now entering his 100th year. As director-general of the General Post Office he was able to assure his audience that " all the resources of the Post Office will be mustered to see that the telegram is delivered before the evening is out."

The four speeches at the dinner were stimulating and admirably delivered. An old bone of contention—why are there not more engineers occupying high administrative posts?—was gnawed once again, though there is not so much meat on it now as there was a few years ago. The implications of this question are sound enough, but let us not refuse to face the facts; in particular, the fact that very few engineers indeed could reach the brilliance, the fluency of exposition, the lucidity of the speech given by Sir Oliver Franks, who proposed the toast of the Institution. A former Professor of Moral Philosophy, and British Ambassador at Washington, who is now chairman of Lloyds Bank, he has a breadth of vision that would be difficult to acquire in the course of an engineering education. What an engineering education can do, as Sir George Nelson showed in his speech, is to give a man the power to move freely at the summit of national and world affairs. But perhaps only a politician like Dr. Charles Hill, who has graduated to politics out of medicine by radio, can hope to be acclaimed before he even opens his mouth.

THE EXPERIMENTAL SPIRIT

6—SPECIAL TYPES: TURBINE LOCOMOTIVES, THE PAGET, THE KITSON-STILL

By C. R. H. Simpson, A.I.LOCO.E.

Locomotive engineers imbued with the experimental spirit have evolved many designs in an effort to make the steam locomotive competitive with electric and Diesel traction. The unsuccessful ones—and as far as possible the reasons for failure—are reviewed in this series of articles.

The many special types, of which but some are referred to here, were all described in the technical Press at the time of their construction and readers who wish for full particulars are referred to those descriptions.

The first steam locomotive to depart radically from the Stephenson form was the Heilmann steam-electric locomotive constructed in France in 1893.[101] This locomotive had a certain amount in common with the modern Diesel-electric locomotive in that an engine-driven generator supplied power to motors mounted on the bogies. The results obtained, from the thermal efficiency point of view, were encouraging, and led to the construction of a second locomotive in 1897.[102] The locomotive ran well and some features, e.g., acceleration, were good, but experience showed—as it was to continue to show—that the gain in thermal efficiency, compared with a simple steam locomotive, did not warrant the high capital cost. Heilmann locomotives had the further disadvantage of being before their time.

TURBINE LOCOMOTIVES

The first locomotive to be powered by a steam turbine was constructed by the Societa Anonima Meccaniche of Milan in 1908. Each of the four driving wheels was driven, via gears, by a separate turbine, the four being arranged in series. What is regarded as the first serious attempt at turbine construction for railway purposes was the Reid-Ramsay turbine condensing locomotive,[103] built by the North British Locomotive Company, Limited, and tried in 1910. In this instance electric transmission was also employed, power being derived from a steam turbine. The object of the condenser was three-fold: to enhance thermal efficiency, to avoid taking on water and to reduce boiler maintenance. While the second advantage may have had no particular appeal in Britain it must be remembered that the builders were catering for world markets. Tests were carried out on the Caledonian and North British Railways, after which nothing was heard of this locomotive.

In 1920 the Swiss Federal Railways obtained a turbine condensing locomotive from the Swiss Locomotive Works. The Zoelly-type turbine was capable of producing 1,500 h.p. for forward running and a Curtis-type turbine of 700 h.p. provided power in reverse. Economies of 25 per cent. in fuel and 50 per cent. in water were reported.

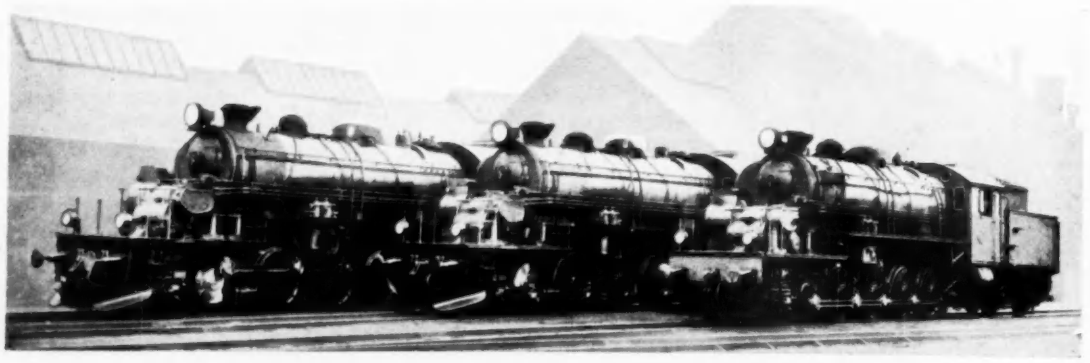
The Swedish Ljungström turbine had a comparatively wide application so far as applications of steam turbines to locomotives were concerned. The first was built in 1921 by Aktiebolaget Ljungström Ångturbin. The turbine rating was 1,800 h.p. at 9,200 r.p.m. This locomotive had the unusual feature of a reversing gear being used in conjunction with a unidirectional turbine. The reported fuel saving in this instance was 50 per cent.

In 1922 the Ramsay condensing turbo-electric locomotive was turned out by Armstrong Whitworth. Generally this had much in common with the Reid-Ramsay locomotive but the condensing arrangements had been developed to such purpose that it was reported that a vacuum of no less than 27½ in. could be maintained despite the limited amount of water which was carried (2,200 gallons). Tests of this locomotive were carried out on the London and North Western Railway.

The final development of the Reid-Ramsay locomotive was the Reid-MacLeod steam turbine locomotive exhibited by the builders, the North British Locomotive Company, Limited, at the Wembley Exhibition in 1924. This locomotive, like that with electrical transmission built in 1910, had two eight-wheeled bogies. In the 1924 engine the turbines were mounted longitudinally on the bogies, the L.P. turbine being on the leading bogie and the H.P. turbine on the trailing one: in each instance the drive was through reduction gearing. The builders estimated the probable economy of fuel and water to be about 50 per cent. and actually guaranteed 25 per cent. Even so there was no buyer. The direct-driven 4-6-2 turbine locomotive built by Krupps for the German Railways in 1924 was not successful. It was impossible to use direct drive efficiently and in this particular locomotive the water consumption was exceedingly high.

In 1926 Beyer, Peacock and Company built the Beyer-Ljungström turbine locomotive tried on the London Midland and Scottish Railway during 1926 and 1927. The boiler was carried on one unit and the condenser and turbine on another. Triple reduction gearing was employed. The locomotive developed 2,000 b.h.p. at 60 m.p.h. and in the course of its trials ran about 5,500 miles. Mr. R. C. Bond has pointed out[104] that the Armstrong-Whitworth and Beyer-Ljungström locomotives both had condensers, with all their attendant complications. Failure to realise expectations was not owing to shortcomings of the turbine but was caused by decreased availability and increased cost and difficulty of repairs, due directly to the complication of the condenser and associated equipment.

Later (1932) the Ljungström Company produced a much-simplified main-line 2-8-0 freight locomotive. This engine was practically identical with other locomotives on the Grängesberg-Oxelösund Railway except that the cylinders were replaced by a turbine driving through gearing and a jackshaft. Trials with this locomotive on 1,500 ton ore trains showed savings of 7·26 per cent. and 14·9 per cent. on coal and water respectively. It was the successful opera-



Non-condensing turbine locomotives, Grängesberg-Oxelösund Railway, Sweden.

Norfolk and Western Railway oil-fired steam turbine locomotive with electric drive.

tion of this engine which directly led to Sir William Stanier's well-known Turbomotive, put into service in 1935. The features of this engine and its operating experiences have been ably chronicled elsewhere.[105]

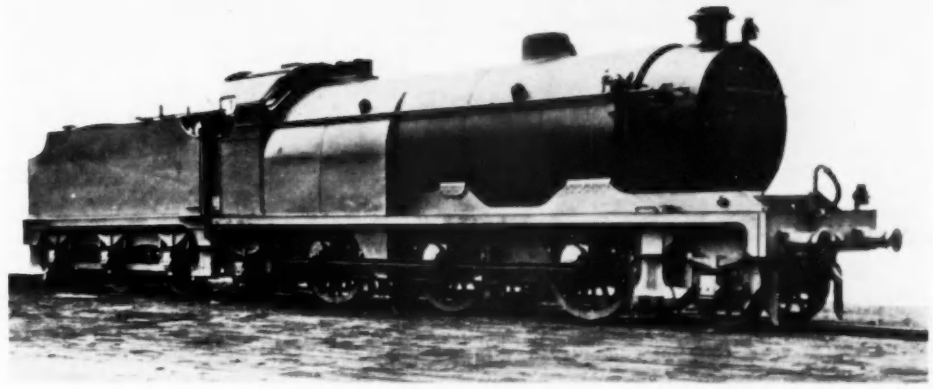
The German Federal Railways carried out tests with a 4-6-0 locomotive (No. 3255)[106] built by Henschel in 1927, in which the exhaust from the reciprocating engine was employed to drive a turbine on the tender. This glorified form of booster was expected to produce about 300 additional horse-power and save coal and water. It appears to have been a somewhat high-priced way of obtaining a relatively small power increase.

The Pennsylvania Railroad, in conjunction with the Baldwin Locomotive Works and Westinghouse Electric Corporation, in 1943 placed in service a 6-8-6 locomotive[107] powered by a 6,900 h.p. turbine receiving steam at 310 lb. per sq. in. from an orthodox boiler having an evaporative surface of 5,002 sq. ft. Drive was through gears, giving a reduction of 18·5 to 1, thus making it the only geared steam turbine locomotive to be built in the United States in recent years. The maximum speed of the turbine was 9,000 r.p.m. and the tractive effort 65,000 lb. Other American applications of steam turbines to locomotives, with electrical transmission, were those for the Union Pacific Railroad—one locomotive in 1938—and for the Chesapeake and Ohio Railroad, who in conjunction with Westinghouse and Baldwin built three such locomotives in 1947.

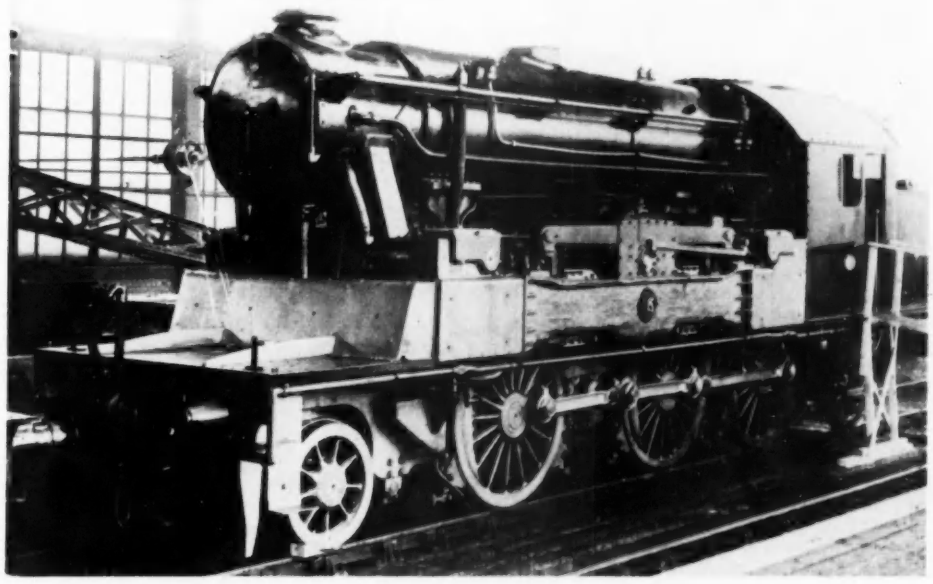
The last application of a steam turbine to a locomotive was on the Norfolk and Western Railroad in 1954. This 6-6-6-6 (shown above) was stated to be the world's largest single-unit locomotive. It turned the scales, with tender, at 586 tons. Steam was provided at 600 lb. per sq. in. by a water-tube boiler. The non-condensing turbine was arranged to drive a generator supplying 12 traction motors, aggregating 4,500 h.p. The results obtained from tests carried out with this locomotive have been published in some detail.[108]

All of the locomotives referred to emphasised that departure from the Stephenson form always introduced complication, frequently necessitated the provision of a special transmission, usually increased weight, and often added greatly to the capital and maintenance costs.

The steam turbine applied to locomotives, like almost all other departures, had its advantages and disadvantages. The wide variation in loading, inseparable from railway work, could never allow it to operate with anything like the efficiency met with in land and marine practices, where conditions of load and speed are constant. Generally, no condenser was available on the locomotive and even when it was the position was a far from happy one. Power required to drive fans in an air-cooled condenser about equalled the extra which was obtained; for a water-cooled condenser, as mentioned in the section of this article dealing with condensers, the amount of water required is large and no overall saving in water could be expected from a locomotive so fitted. A turbine locomotive required very careful handling. Among other idiosyncrasies the turbine required a considerable amount of steam to be passed through the blades before rotation commenced. Unless great care was exercised the boiler pressure could be fairly quickly and substantially lowered, with the harmful results associated with "breathing." The limitations of the steam locomotive imposed by boiler requirements of all descriptions, were in no way improved by the substitution of a turbine for the cylinders.



Paget locomotive.



Kitson-Still locomotive.

On the credit side the turbine, by virtue of its perfect rotational balance and its constant torque, produced a very good riding locomotive, well suited to high-speed operation.

In the 1920's and 30's the steam turbine offered a greater challenge to the Stephenson form of locomotive than any other special type and many were constructed. It must be added that the number of designs was not greatly below the number of locomotives.

THE PAGET LOCOMOTIVE

The Paget locomotive, references to which already have been made, was built at Derby in 1908 to the designs of Cecil Paget, who was at the time works manager there. The engine fairly bristled with originality, but basically the designer's aim was to achieve good balancing, with no reversal of thrust in the moving parts. There were eight single-acting 18 in. by 12 in. cylinders, the steam distribution to which was controlled by rotary valves. The cylinders were so arranged that a pair, placed back to back between two axles, was almost the equivalent to

one cylinder with trunk pistons working in opposite directions, thus cancelling out disturbing forces. Paget's idea was said to have been inspired by a study of the Willans high-speed central-valve engine which gave such trouble-free service in the early days of electric lighting. The locomotive failed to emulate this service and in fact encountered serious difficulties, chiefly on account of the differential expansion of the sleeve valves and liners. The boiler had the orthodox water legs omitted, but nevertheless steamed well.

To-day, there is a tendency to regard this locomotive as freakish, but in the opinion of Mr. J. Clayton,[109] who was in a favourable position to decide, this was not true: the engine was an honest endeavour to solve problems in a new and simpler way. It ran well and reached speeds of over 80 m.p.h. despite the fact that the wheels were only 5 ft. 4 in. in diameter.

KITSON-STILL LOCOMOTIVE

In the early days of Diesel locomotive development, attempts were made to use direct drive. In the first main-line Diesel locomotive, built in 1913 by Sulzer Brothers and A. Borsig, the steam cylinder was replaced by a Diesel cylinder driving on to the crankpin in the usual manner. An obvious limitation of this arrangement is the inability of Diesel power to start the locomotive from a state of rest, and to overcome this compressed air was utilised until a speed was reached at which the Diesel could function as such. This arrangement required enormous quantities of compressed air and had the further fatal disadvantage that the air expanding in the cylinders produced intense cold, making initial firing difficult when the change-over was made to Diesel working. After the test every commentator stated that they had known the idea would not succeed—but not one had prophesied why!

The Kitson-Still locomotive overcame the difficulty by employing steam on one side of the piston and Diesel on the other. This arrangement appeared to hold the attraction of high thermal efficiency, as steam was employed at starting, and the eight 13½ in. by 15½ in cylinders were consequently hot when the time came to cut in Diesel working at about 4 m.p.h. Above 5 m.p.h. the use of steam could be dispensed with and all work performed by Diesel power, unless conditions were sufficiently arduous to require both steam and Diesel to operate together. The maximum internal combustion i.h.p. was 950 and the maximum combined i.h.p. 1,300. Further description is unnecessary as the locomotive has been fully described elsewhere.[110] It was unfortunate that the development work on this locomotive was carried out at the time of the great depression. The Kitson-Still locomotive was very nearly successful and, though speculation is perhaps idle, had times been more propitious it might have been further developed. On the other hand it cannot be denied that it possessed considerable complication—the curse of the steam locomotive man at all levels—and it could have been missed out on that score alone. It can never be sufficiently emphasised that, with a locomotive, a development which results in an appreciable (8 to 10 per cent.) thermal saving may in fact lead to an overall loss on the year's working if it necessitates the engine being withdrawn from traffic for about one week a year for attention that would have been unnecessary had the equipment not been fitted.

To be continued

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Letters to the Editor

HOW OLD IS THE ROLLER BEARING?

SIR, I read with considerable interest the article in your issue of January 4, "Bearings Since the Stone Age"; and the more so as I had a contribution prepared dealing with almost the same subject. Some of the material contained in Dr. Davison's article was necessarily also included in detail in mine, but I had in addition some information which is very largely complementary to his.

In seeking evidence of the origins of the rolling bearing it is useful perhaps to establish firstly a definition of a bearing. It may be described as a device which sustains the load while permitting two parts to have motion relatively to each other, theoretically without friction and therefore without resistance to motion, and subject to the minimum of wear. The need for a bearing presupposes the existence of two such related parts, the earliest example of which was undoubtedly a wheel on an axle. In the search, therefore, for the earliest known uses of a bearing it is necessary to look at the earliest known forms of the wheel.

In the most remote times, it was recognised that it was possible to reduce resistance to motion by the presence of an intermediary between the two opposing surfaces. The *Encyclopaedia Britannica* refers to chariots found in the tomb of Yuaa and Thuiu (*circa* 1500 B.C.) which had the remains of a lubricant, probably an animal tallow, on the axle. These particular chariots, while not the earliest known examples of wheeled transport, provide evidence of an intermediary of fat as a pad or cushion between moving parts to reduce friction. All later developments in bearings were concerned with either the use of a more efficient intermediary, or the more positive formation and preservation of the intervening pad of lubricant. To the latter end, were directed the many improvements in plain or oil-film bearings. In the former category, fall all those devices employing some form of rolling intermediary. My examination here is more especially concerned with this class.

As mentioned above, the wheel and its axle constitute the earliest revolving parts in which a bearing may be found. The origin of the wheel is lost in antiquity. Popular theory, however, suggests it developed in stages, from a tree trunk to a trimmed log, thence through log rollers to solid disc wheels which were at first fixed to the axle and later revolved on it. However logical a theory of development this may be it is mere conjecture.

Dr. V. Gordon Childe, Director of the Institute of Archaeology of London University, in his

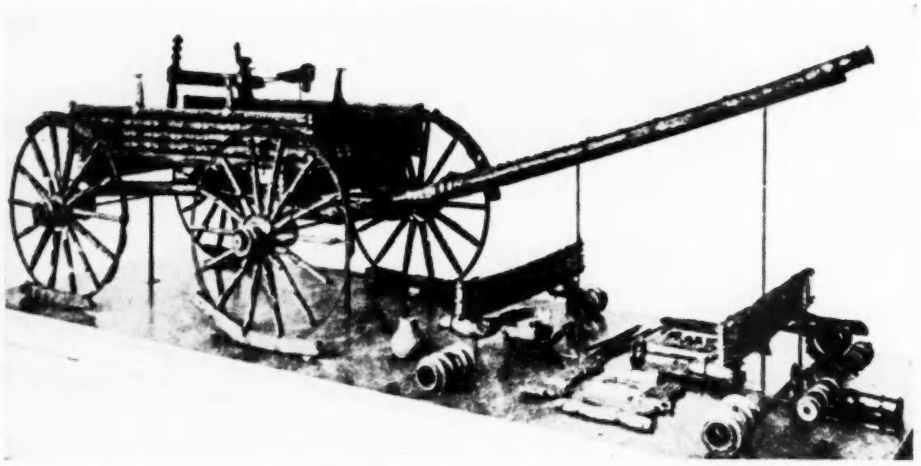
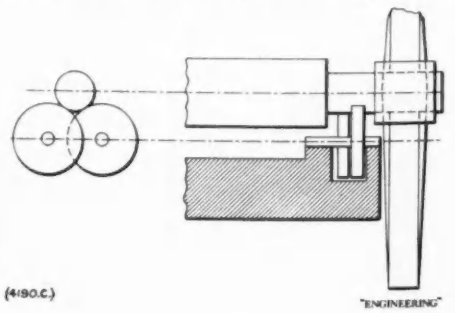


Fig. 1 Hubs said to employ cylindrical sticks as roller bearings were used in early carts from Dejbjerg, one of which is shown in its present state of restoration at the Danish National Museum.

Fig. 2 (left) Bronze collars used in the hubs of the Dejbjerg carts.

Fig. 3 (right) The rolling bearing design by da Vinci is interesting in that it foreshadows the friction wheels which later were to form the subject of British patents.



(4190.C.) "ENGINEERING"

paper " The First Waggons and Carts—From the Tigris to the Severn,"[1] shows that the wheel was in use during the Fourth Millenium. Thus, if man is taken as evolving during the Pleistocene period, he had some 50,000 years through which his knowledge of easing means of transport could develop from the use of a skid or log roller to a true wheel.

Dr. Childe, on the evidence available, considers the wheeled vehicle to have been invented in Sumer before 3500 B.C., the earliest documentation being a script sign on a tablet, in the form of a sledge mounted on wheels. It is not, however, until later that any details emerge, when, in Mesopotamian tombs of the Early Dynastic I period (*c.* 3100 B.C.), remains of wheeled vehicles were found. It is interesting to note that the first actual examples of wheels found were constructed of three shaped wooden planks clamped together, having a wooden felloe protected by a studding of copper nails. If the wheel had, in fact, developed from the solid disc section of a log or tree a considerable step forward in construction had clearly been made by this time. Of the four wheels found, the excavator reported that only a thin film of wood survived at the centre, but six little nails were present at the centre of each wheel. The function of these was not recognised, and Dr. Childe asks " Can they have been bearings ? " In his same paper, Dr. Childe refers to a ceremonial waggon from Dejbjerg of the period of the Danish Iron Age (*c.* 500 B.C.), the wheels of which ran on bearings of cylindrical sticks. One of the existing Dejbjerg carts is shown in Fig. 1 in its present state of restoration at the Danish National Museum, Copenhagen. A bronze collar for one of the cart's hubs appears in Fig. 2.

These particular examples are the earliest indication of any form of rolling bearing. Although rollers were used for rectilinear motion about 330 B.C.,[2] it is not until some few hundred years later that the next recorded application for rotary motion is found. This was in the form of bronze balls revolving on trunnion pins to effect movement of a turntable, and was attributed to the period of the Emperor Caligula (A.D. 12 to 41). An illustration of this bearing appeared in an article[3] by Dr. C. St. C. Davison, Assistant Keeper, Science Museum (ENGINEERING, January 4, 1957, page 2).

Dr. Davison also makes mention of other bearing references during the 15th and 16th Centuries by Agricola, Ramelli, Cellini and Leonardo da Vinci, which need not be repeated here. Of these, the rolling bearing design by da Vinci[4] is perhaps the most interesting, as it foreshadows the friction-wheel designs which later were to form the subject of British patents. A sketch of da Vinci's design is reproduced in Fig. 3.

In 1710, a design submitted by De Mondran with anti-friction rollers for carriage wheels was approved by the Paris Academy of Science.

It is not, however, until the institution of the British system of patents that detailed descriptions of bearings can be found. The earliest of such references occurs in No. 543[5] of 1734 to Jacob Rowe, who claimed the introduction of friction wheels, that is, " wheels caused to turn under the axis of the heavy wheels, or against the point or place where the said axis must bear." Anti-friction wheels of the same basic character are also described in British Patents No. 714 of 1757 to John Ladd, No. 862 of 1766 to Yonge and Barclay, No. 2057 of 1795 to James Edgell and 4709 of 1822 to Joseph de Baader.

The rolling bearing designs of the 15th and 16th Centuries were almost without exception for carrying thrust loads; and friction wheels—which must in fact be considered as having been originated by da Vinci—represent the rolling bearings proposed for radial loads prior to the invention of Garnett in 1787.

Garnett's roller bearing was followed by Vaughan's ball bearing in 1794, which was the first practical radial type employing balls, and it is interesting to observe that it included the first form of filling slot. Neither Garnett nor Vaughan indicated any type of separate inner race, the rolling elements—which Garnett said could be " cylinders or cones or conic frusta "—revolving directly on the axle or shaft. A similar bearing to that of Garnett was the subject of British Patent No. 1602, in the same year, to Watkin George.

Garnett also provided a form of separator, comprised of annular discs connected by bars between the rollers to form roller cavities. This was probably the first practical cage, although Charles Greenway, in his later Patent No. 8333 of 1840, claimed a cradle or cage with pockets shaped to suit the contour of the rolling elements which could be balls, or rollers of spherical, cylindrical or conoidal shape.

Garnett, Vaughan and Greenway were all British, and their inventions are the real practical antecedents of all the main types of rolling bearings in use to-day.

Yours faithfully,
J. T. EMMERTON.
(In charge of Patents Department,
British Timken Limited, Birmingham.)

134 Tile Cross-road,
Birmingham, 33.
February 4, 1957.

REFERENCES

[1] *Proceedings of the Prehistoric Society*, 1951, Dr. V. Gordon Childe.
[2] Marcus Pollio, 1548.
[3] ENGINEERING, January 4, 1957, page 2, by Dr. C. St. C. Davison.
[4] *Codice Atlantico*, by Leonardo da Vinci, c. 1500.
[5] British Patent Specifications.

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SELLING CANADA

SIR, Are you not, perhaps, a little too despondent in saying, in connection with the CABMA Register (" Privileged Advertiser," ENGINEERING, February 22, page 248), that the Canadian market requires a great deal of selling to the average British manufacturer?

British exports to Canada, amounting to very nearly 500,000,000 dols. in 1956, must surely represent successful efforts, not only by the large and justly famous firms in the aircraft and engineering industries, but also by a whole host of " average " manufacturers in all kinds of business.

Britain's record exports to Canada in 1956 were only about 9 per cent. of Canada's total imports, as against this country's 17 per cent. share of the market before the war. This fact shows that there is still plenty of room for the expansion of Britain's exports in what must be one of the most dynamic and fastest growing markets in the world. It should not be too hard to " sell."

Yours faithfully,
P. S. YOUNG,
Chief Executive Officer.

Dollar Exports Council,
21 Tothill-street,
London, S.W.1.
February 26, 1957.

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TRAINING MARINE ENGINEERS

SIR, I regret that your report of the symposium on " The Education and Training of Naval Architects and Marine Engineers," in your issue of February 15, does not refer to the Institute by name until the third column on page 223. This symposium was organised jointly by the Institution of Naval Architects and ourselves.

The fact that the symposium was held in the Weir Hall was simply because it was the turn of the Institution of Naval Architects to have one of these joint meetings in their building; the previous such meeting having been held in this building as recently as last October, when the symposium on " Fires in Ships " was presented.

Yours faithfully,
J. STUART ROBINSON,
Secretary.

The Institute of Marine Engineers,
London, E.C.3.
February 22, 1957.

THE BARE PLATFORM

SIR, I have been a reader of ENGINEERING for over forty years and a traveller on Irish Railways for even longer than that.

Your leading article entitled " The Bare Platform," on page 225 of your issue of February 22, contains a reference to Irish railway travellers at the end of the second paragraph, which states: " The Irish never see each other in railway carriages because one or other of them has a goose or a pig on his lap." Personally, I have never seen either.

This reference may have been intended to be humorous; if so, it is in poor taste. Otherwise, it appears to be either deliberately misleading or due to invincible ignorance. Whatever way it was intended, it is unworthy of a leading article in ENGINEERING.

Yours faithfully,
H. N. WALSH.

47 Sunday's Well,
Cork.
February 28, 1957.

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Obituary

MAJOR R. H. MAYO

Aircraft Designer and Consultant

The death occurred in London on Tuesday, February 26, of Major R. H. Mayo, O.B.E., M.A., A.M.Inst.C.E., F.R.Ae.S., known to the general public mainly as the designer of the Short-Mayo composite aircraft.

Robert Hobart Mayo was born on September 25, 1890. He was educated at Magdalen College, Cambridge, and in 1914 he was appointed head of the experimental department of the Royal Aircraft Factory. He joined the Royal Flying Corps and served as a pilot from 1915 to 1917, in France and at Martlesham Heath. In 1917 he became head of the aeroplane design section at the Air Ministry. He left the Air Ministry in 1919 to become a director of Ogilvie and Partners, consulting engineers.

In 1925 he became consulting engineer to Imperial Airways Limited, and from 1936 to 1939 he was their Technical General Manager. It was during this period that he designed the composite aircraft, which was built by Short Brothers, Limited, and consisted of a four-engined flying boat, the Maia, from which was launched a highly-loaded small seaplane, the Mercury, designed to carry express mails and freight. The long-distance world record for seaplanes set up by Captain D. C. T. Bennett (now Air Vice-Marshal) in the Mercury in 1938, between Scotland and South Africa, is still unbroken. Major Mayo subsequently acted as technical adviser to B.O.A.C. Among the aeronautical offices he held, he was " vice-president of the Federation Aéronautique Internationale and a past chairman of the Air League of the British Empire.

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HAWKER EXPANSION

The administrative, design, experimental, research and development sections of the Hawker Aircraft Company, Limited, are ultimately to be transferred to a new headquarters on the site of the existing Hawker factory at Richmond-road, Kingston, from the present headquarters in Canbury Park-road, where the company began its life under Sir Thomas Sopwith in 1910.

The rebuilding scheme, forms part of the big expansion of research facilities now being carried out throughout the Group. The new office block of four storeys will contain a new design office on one open floor under a 400 ft. span daylight roof, and provision is made for the most modern equipment, such as the Flight Simulator and the Ferranti Pegasus computer, both of which are already in use in the existing design office. The new research and development building, which will be completed early this summer, will cover 100,000 sq. ft. under one roof at the rear of the Richmond-road site.

Weekly Survey

Cover Picture: *Shipbuilding is one of the oldest industries, and one on which Britain has long depended for a substantial part of her revenues. Our illustration shows the river end of some slipways with vessels under construction.*

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European Coal Supplies

Figures for European hard coal production issued last month by the Economic Commission for Europe show that the virtual stagnation of output which has been a feature of the British coal industry in recent years also affects most European countries outside the Iron Curtain. An exception is Western Germany where hard coal production rose by 2·8 per cent. in 1956 to 134·4 million metric tons. This figure is, however, still below output in 1937. By contrast, production in Czechoslovakia and Poland has been increasing steadily: in the former case, 1956 output at 23·5 million metric tons was 40 per cent. up on 1937 while Polish production at 96 million metric tons showed an increase of 45 per cent.

For the whole of Europe excluding the U.S.S.R. hard coal production reached 622·1 million metric tons, a record figure which compares with previous peaks of 616 million metric tons in 1955, 609 million metric tons in 1954 and 607 million metric tons in 1929. The increase of 6 million metric tons in 1956, however, failed to meet the increased European demand for coal, and imports from the United States rose by 13·7 million tons to 38·4 million tons, a record figure which surpasses even the previous peak of 37 million tons in 1947, when much of the European industry was still suffering from damage and dislocation due to the war.

Even those European countries which have succeeded in expanding production of coal in recent years had less available in 1956 to supply to other European countries, imports from Poland showing a decline of 0·2 million tons and from Western Germany 0·5 millions. The fall in imports from Belgium, France and the United Kingdom was very much more pronounced. To a small extent, the declining supplies were made good by a rise of 0·4 million tons in imports from the U.S.S.R. whose output of hard coal at 429 million tons in 1956 showed an increase of nearly 10 per cent. compared with 1955. If production continues to expand at this rate, will the U.S.S.R. in time become an important supplier to Western Europe?

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Electricity Tariffs in Europe

The essential aspects of the regulations governing the supply of electricity in 13 countries are dealt with in a pamphlet recently issued by the Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris XVI. The regulations applying to the rates for energy require the undertakings to give fair and equal treatment to all consumers to whom the same conditions apply, so that there can be no unjustifiable discrimination. Consumers are also generally entitled to choose the tariffs applicable to their particular case. In Germany, Austria, France, Greece, Norway and the United Kingdom electricity supply undertakings must publish the general tariffs applicable to some categories of consumer, but while in the others there is no such obligation, the rates, especially those applicable to household consumers, are usually brought to the notice of the public. In some countries the tariffs have to be approved by Government or local authorities, but it is only rarely stipulated that special rates shall be granted to the communal authorities or to certain categories of consumers. Exceptions to this rule are France, Switzerland and Belgium.

The determination of rates varies according to the way in which electricity is used, and above all depends on the method adopted for generating it. The two types of tariff generally employed are the two-part and the block. In the former, the fixed charge is usually related to the actual or potential demand and covers part of the interest, depreciation, etc. An outstanding feature is the tendency to regard consumption and maximum demand as the basic criteria for the classification of consumers. In several countries, however, the fixed-charge component or size of the block is for household consumers assessed on the number of rooms, for rural consumers on the area under cultivation, and for power supply on installed capacity. A second method is to adopt different standing charges for different classes of consumers. In Italy there are a number of cases where a flat rate with no fixed charge is applied. Such rates often include provision for guaranteed minimum consumption and are employed in the least industrialised areas.

Sometimes the price of electricity may vary on a geographical basis. France, for instance, is divided into zones in which the rates vary according to the distance of the consumer from the place of production. In Sweden special industrial tariffs are applicable in the northern part of the country. In O.E.E.C. member countries electricity undertakings are entitled to demand some contribution towards the cost of connection to the mains. In France this cost falls entirely on the consumer. In others, Belgium and Germany, it is negotiated between the consumer and supplier.

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European Nuclear Plant Market

The British Government's decision to assist the European Atomic Energy Commission (Euratom) with plant, engineers and training facilities, matches the offer made by the United States. It was a necessary counter if the market for nuclear plant and equipment constituted by the Euratom countries—Belgium, France, Germany, Italy, Luxembourg and the Netherlands—were to remain open to British manufacturers. A refusal to co-operate would almost certainly have lost a potentially very strong position. The three Euratom representatives who spent last week in this country exploring possibilities of co-operation and also the plant supply position, hinted that the six countries concerned are now unlikely to build their own gaseous diffusion plant to produce enriched uranium fuel for nuclear reactors. Some of the initial orders for atomic power stations scheduled under the Euratom plan will now almost certainly go to British firms.

The Three Wise Men, as the representatives of Euratom are known, consider that Western Europe should begin as soon as possible to install about 3,000 MW of capacity each year. The alternative—imported fossil fuels—is unattractive and could seriously lower the Euratom countries' ability to compete in world markets. British co-operation should enable a much speedier start to be made than would otherwise be possible. The offer includes not only the supply of complete power stations and fuel but also the services of a team of experts to work on development and construction plans of power stations and research facilities. In addition, training facilities will be made available at A.E.R.E., Harwell, for the training of Euratom personnel.

Germany's own programme was taken a step further with the placing of an order last week for the first privately owned experimental reactor of 15 MW electrical output (nearly 60 MW heat rating). The contract, estimated to be worth more than £3 million, was placed with the Anglo-American Group comprising American Machine and Foundry (A.M.F. Atomics) and Mitchell Engineering. The German Minister for Atomic Affairs, Herr Balke, who made the announcement, is to visit Britain shortly to discuss the commercial efficiency of power reactors, heat exchangers, pumps and other equipment. Euratom experts are believed to favour two American designs using enriched uranium (the boiling-water and pressurised-water reactors) and a Canadian design of a natural uranium reactor cooled by heavy water and not by gas as at Calder Hall. British co-operation with Euratom should therefore provide contractors with the opportunity to gain experience with reactors other than those now being built in this country.

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Treaties with Australia and Japan

The *status quo* has been largely maintained in two trade treaties signed last week. The new agreement signed between Britain and Australia maintains preferences, albeit with reduced margins, and that signed between Britain and Japan shows very little change from the old. Yet the latter has emerged after long months of negotiations in London which at one time led to the belief that considerable concessions would in fact be made to the Japanese demand for a relaxation of British import quotas. The Japanese Government have expressed considerable disappointment with the results of the talks, pointing out that some concessions were expected following the substantial import relaxations they made last year. They expect a considerable increase in their country's import requirements for machinery but point out that their Sterling reserves have fallen from £100 million to £30 million in one year. Total Japanese exports to the Sterling area are limited to £300 million, an increase of £50 million over last year's ceiling but far lower than the Japanese had hoped for.

The agreement with Australia was signed in Canberra. According to the President of the Board of Trade this shows "the determination of both countries to maintain historic ties in spite of changing conditions." The Australian Minister of Trade, Mr. McEwen, said that the agreement retained tariff preferences and duty-free entry for Australian goods in Britain and also maintained tariff preferences for British goods in Australia subject to reduction in guaranteed margins. How significant the latter will prove to be is hard to assess. The Australians have long maintained that excessive preference margins operated against imports from foreign countries to an extent which placed a heavy cost burden on Australian industry.

Both treaties show a grudging acceptance of the world pressure for freer trade. Sooner or later, and possibly very soon if the free trade area develops in Europe, British goods will have to compete on equal terms. Australia and Japan, market and competitor, may have even more to say by 1960.

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Post-Graduate Nuclear Power

The Imperial College of Science and Technology now announces the first of the educational developments which follow the recent appointment of Dr. J. M. Kay as Professor of Nuclear Power. A special one-year post-graduate course in nuclear power has been arranged. Enrolments will begin at once for the first class, which will start in October, 1957. The course is based on the belief that nuclear power is not a distinct technology but a new field for the application of existing basic branches of engineering and applied science. Entry to the course will be open to students having a good honours degree in mechanical, civil, electrical, or chemical engineering. In the general arrangements, the course will follow the common practice of the full-time post graduate courses of the College. It is understood that students taking this course will be eligible for D.S.I.R. Advanced Course Studentships. Further particulars may be obtained from the Registrar, Imperial College.

The syllabus will include a number of back-

bone lecture courses on basic nuclear physics, nuclear reactor theory, nuclear fuel technology, biological effects of radiation, and the design and construction of nuclear reactors for power generation. Optional lecture courses will cover such subjects as advanced fluid mechanics and heat transfer, the mathematical theory of neutron diffusion and transport theory, properties of special materials and unusual metals, isotope separation, fuel cycles, thermal design of nuclear power plants and steam cycles, instrumentation and control theory, the design of reinforced concrete structures, etc. Each student will be advised to make a suitable selection from the available lectures so that he can retain his primary allegiance to the particular main branch of engineering in which he graduated. Practical laboratory work will include the demonstration of neutron sources and gamma radiations, methods of detection of neutrons and radiation, counting equipment, measurements of neutron diffusion, the use of a reactor simulator, experimental work on fluid flow and heat transfer, and a number of other mechanical engineering problems.

One of the most serious difficulties at the present time is the shortage of first-class design engineers. While it is not possible to train such engineers completely at a university, special effort will be made in this course to cover the approach to engineering design. The principal aim of the course in fact will be to meet the needs of the engineering industry engaged in the field of nuclear power. At a later stage the College will be announcing related developments in other aspects of nuclear technology and in research and development. The course will be under the direction of Professor Kay. Because of its wide scope it is being organised in association with many Professors of other subjects, in particular: Professors Ball (physical metallurgy); Blackett (physics); Danckwerts (chemical engineering science); Newitt (chemical engineering); Saunders (mechanical engineering); and Tustin (electrical engineering).

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Tanker Needs and Tanker Plans

The world's need for oil tankers would appear to be very much as Mr. Stavros Niarchos put it some months ago—very much greater than the world's capacity to supply them. To a large extent this applies also to other ships but again last week concrete evidence was provided that tanker orders would be pre-eminent.

Announcing their plans to raise outside finance for £40 million worth of tankers already ordered, the British Petroleum Company foreshadowed orders for 20 to 30 ships costing between £80 million and £100 million. They also stated that the tankers ordered this year will not be delivered before 1961. But B.P. are not alone: the Shell group, who recently announced a £30 million tanker finance scheme, will doubtless come in with a long-term order programme before long, as will Esso Petroleum. Among those recently in the oil tanker field, the British and Commonwealth Shipping Company—the holding company for Union-Castle and Clan Line Steamers—placed an order for a 47,000 ton d.w. tanker with Swan, Hunter and Wigham Richardson for delivery in 1964. The Peninsular and Oriental Steam Navigation Group are said to have started negotiations with the oil companies for the charter of tankers yet to be built. The first of a fleet of 25 vessels—one of 37,000 tons d.w.—is reported to have been chartered for a five-year period when it is delivered in 1959.

To these companies' programmes could be added many others including some, such as Niarchos and Onassis, who compete for building capacity in Germany, Japan, the United States and other countries as well as Britain. Added to the difficulties of finding enough yards are those of an acute shortage of steel plate and of yards capable of accommodating the large vessels (ore carriers as well as tankers) now in increasing demand. The British shipbuilding industry failed to contribute to the 20 per cent. increase in world output last year. Never before has it had so glorious an opportunity and so urgent a need to expand and modernise its capacity.

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Co-ordinating Land and Sea Transport

Much is heard of the effect of road transport competition on the railways but very little of the effect on coastal shipping. The Annual Report of the Chamber of Shipping of the United Kingdom for 1956-57, however, in commenting on the competitive difficulties of the coasting trade, points out that there have been more withdrawals of established liner services and a further decline in the number of small tramp vessels. It attributes the liner problem mainly to road competition from independent road hauliers coupled with a further increase in the use of C licence vehicles. This is to be the subject of a special report from the Coasting Liner Conference to the Coastal Shipping Advisory Committee.

The small coasting tramp is affected mainly by rail competition. The Chamber of Shipping point out that since the railways are losing between two-thirds and three-quarters of a million pounds a week, it is not surprising that coasting owners consider railway rates generally to be at too low a level. They are further concerned at the proposals in the White Paper of October, 1956, under which the revenue deficits of the British Transport Commission may be charged to a special account and covered by a loan of £250 million from the Consolidated Fund. Discussions have been held with the Minister of Transport on this point, and he has given an assurance that it was not the Government's intention that the Commission should use this financial assistance to compete unfairly with other providers of transport.

Close co-operation between shipping interests and road and rail transport operators is of great importance in reducing delays and congestion at the docks and in ensuring quick turn round of shipping. The Chamber of Shipping report also refers to this and points out that, following discussions between shipowners and traders through the Ports Users' Committee and the British Transport Commission, the latter announced improved arrangements for dealing with export traffic by rail towards the end of 1956. The main scope for future improvement probably lies in improving road access to the Ports.

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For Galley or Kitchen

A good many years ago the ship's galley relied almost entirely on solid fuel for heating. More recently oil has tended to play a larger part, and most recently still electricity is taking over the general field. This curiously parallels the development of propulsive power in ships, and shows how the development of one section is dependent on another. It is the development of three-phase alternating current systems in ships which has rendered possible and economic the use of large electrical apparatus. It has also raised problems of its own, because the three-wire system commonly employed, operating at 440 volts, requires care for insulation and switches, although there are gains in the smaller size of conductor needed.

Examples of all three types, coal, oil and electric, of cooking apparatus are being shown by the Carron Company of Falkirk, at their London showrooms, 15, Upper Thames-street, London, E.C.4, so that shipowners may know the range of equipment that is now available. Apart from coal, oil and electric heating, there are also units employing low pressure steam both for cooking, as in a large vegetable cooker, or for holding, as in a serving table which is placed intermediately between the galley and the dining saloons. Stainless steel is playing its part here as in the modern domestic kitchen and the "fitted" galley is now as familiar as the fitted hotel or house kitchen. Extras such as mixers are also very much in evidence, the more so perhaps, as the catering demands are increased. Even plastics have invaded this field for there is on display a sideboard, which is made from block-board covered with Marleyfilm vinyl sheeting. There are also examples of tea and coffee making equipment. It should be noted in passing that only about half the firm's output of cooking equipment is supplied to ships: the rest is for hotels and canteens on land. Other items of ship's fittings on display include a very wide range of side lights and windows, including circular swing and horizontal and vertical sliding types. Here again, the modern tendencies in shipbuilding are reflected for both framed models for bolting in place and fabricated designs for direct welding to the ship's hull, are displayed. An electrically driven cargo winch completes the range of items in the exhibition which opened on February 26 and will last until March 15.

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Automation in Banking

The decision, announced last week, of the eleven major United Kingdom banks represented on the London Clearing Bankers Committee to adopt a nation-wide system for automation in banking, will provide a further important market for manufacturers of electronic equipment and office machinery. The electronics sub-committee of the Committee of the London Clearing Bankers was set up a little over a year ago and has now sent a technical description of the requirements of the scheme to the principal equipment manufacturers; it is expected that the first elements of the system will come into operation in about two years time.

It is proposed that cheques should be marked with coded information in magnetic ink. Among new equipment required will be machinery for printing such inks and for reading characters less than one-eighth inch high printed on cheques, pay-in slips and other documents. Electronic computers will also be required for use at district headquarters and possibly at some individual branches. Special printers will also be required for translating electronically stored or magnetically printed data into the form of visible printed bank lists or customer's bank statements, as well as special equipment for transmitting accounting information from bank to bank.

It is not expected that the adoption of the new system will result in redundancy of staff since it must inevitably be spread over a number of years. Moreover, many banks are already suffering from shortage of labour for the clearing of cheques. It is claimed that the system outlined is more comprehensive than that put forward in any other country. While it is essential that there should be a good deal of common ground in the system installed by individual banks in order to ensure the efficient development of automatic cheque clearing methods, the system will permit the development of a number of different types of automatic systems in the field of branch banking.

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Increased Turnover and Profit

By and large 1956 has been a very good year for medium and heavy engineering. There is ample evidence of this among company reports published last week. Broom and Wade, Limited, manufacturers of air compressors and pneumatic drills and tools, report an increase of 12 per cent. in trading profit, to £623,658 for the year ending September 30. Mr. Harry S. Broom, the chairman, reported that increased output had enabled the company to quote quicker deliveries and to allocate—"for the first time for many years"—part of production to the building of stocks of overseas agents and subsidiaries. Increasing competition makes this step an important one, and the company expect this will help them to

maintain their order book " at its present high level."

For the same period the Power-Gas Corporation group have also done well, trading profit being up about 4 per cent., to £859,714. The value of orders received during the year amounted to £12·5 million, which was well above the average of recent years. Their chairman, Mr. N. E. Rambush, mentioned that this included contracts to a substantial value for technical and engineering services and commented " we foresee an increasing volume of contracting of this nature which enjoys the advantage of not being affected by limitations of steel supplies to our works."

The shortage of steel is not confined to large users of plate and strip such as the Power Gas Group. Mitchell, Shackleton and Company, Limited, crankshaft makers and forgemasters, complain bitterly of the shortage of suitable size and quality in forging steels. Their chairman, Mr. Joseph Mitchell, said that " as the supply of billets and blooms is almost non-existent, it is necessary to convert the supplies of ingots that are available," pointing out that he could not foresee the end of this " costly procedure." Despite this shortage, and a continuing shortage of skilled labour (in Patricroft, Manchester) the company, who supply mainly the builders of heavy oil engines, increased their turnover and profits. There is very little wrong so far with the performance or prospects of medium and heavy engineering companies. Their general position is aptly summarised by Mr. F. E. Hill, chairman of Foster, Yates and Thom, Limited, heavy precision engineers and boiler makers: " . . . our trade generally continues to expand. The Company's work in progress now stands at the highest in its history and the order position continues to be most satisfactory. The country seems always to demand more goods than the available material can satisfy and the management and staff are continually battling to overcome the difficulty of shortages, particularly where steel supplies are concerned."

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Profits and Prospects

For the first time since the war one of the electrical engineering giants, Associated Electrical Industries Limited, show sharply reduced trading profits—down by 32 per cent., from £15·3 million to £10·3 million. The dividend of 15 per cent. has been maintained on the company's increased capital but nothing has been added to reserve for the replacement of plant and equipment. The allocation of £¾ million made in the first half of the year has been withdrawn. There is no clear, and certainly no single, explanation for the magnitude of the set-back. The Government's restrictions on the credit sale of consumer appliances were doubtless a factor, but the fact remains that several of the Group's main competitors in this field have done relatively very much better. Extensive reorganisations within the Group, taking place at a difficult time of falling demand for some products coupled with generally rising costs, may have had a disruptive effect far greater than would have been the case in more normal circumstances. Nonetheless, the Group's future prospects appear to be good.

Another shock, perhaps more generally expected, was the announcement by the Rootes Group that a trading loss had been made in the six months ending January 31. This represents the darkest period in the motor industry's crisis and it would be surprising if any of the leading companies had made large profits during that time. Motor vehicle production is now rising rapidly, with reports of overtime, night shift and heavy recruitment. But the spring and summer months will have to be very good indeed to offset the tragedy of the last half year.

The hope that the current recovery in demand would make good what the chairman of Associated Motor Cycles, Mr. S. R. Hogg, called the " deplorable " first four mouths of 1956 was expressed by him when he reviewed the company's prospects in his annual report published last week. He said that there has been a marked improvement since the beginning of this year which corresponded to the reduction of the initial deposit required on a hire purchase payment from 50 per cent. to 20 per cent. This has, without doubt, been the principal factor in the recovery of the motor vehicle and motor cycle industries.

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Rolling Stock

The smart recovery in the profits of G. D. Peters and Company, Limited—from £66,000 to £165,000—suggests that the decision of the British Transport Commission to use vacuum brakes on goods wagons may already have had an impact on the company's affairs. Last year their chairman reported that they had been asked to undertake an " immense programme for the supply of brake cylinders for the equipment of existing unbraked wagons." He is now expected to report that contracts have been placed, although there has been a good demand for the company's other products, which include pneumatically operated doors for public transport vehicles, industrial and commercial buildings, as well as machine tools and welding electrodes.

Another company supplying the rail and road vehicle industries, Jonas Woodhead and Sons, Limited, report greatly increased demand for suspension springs and shock absorbers for rail and heavy road vehicles, though in their case the reductions in the purchasing schedules of motor car manufacturers somewhat offset the increase. Other products, including springs of all types and constructional steelwork, helped to produce a substantially increased turnover for the group as a whole. Mr. Michael Moore, the chairman, did not exclude the possibility of a recovery in the motor industry " rather sooner than seems likely at the moment." In this respect the chairman of Tecalemit Limited was somewhat more reticent. Having reported increased activity in most of the company's departments and a £50,000 increase in the group's trading profits to nearly £495,000, he limited himself to forecasting a resumption of the group's expansion " when the present crisis has passed." Those were very much the feelings of Mr. A. P. Hague, chairman of the Cronite Foundry Company, manufacturers of nickel-chromium alloy castings. As in the case of Tecalemit, the motor industry is an important outlet, though perhaps less so. On the other hand, the supply of nickel and nickel-containing scrap is for them a serious limiting factor.

A recent announcement by F. H. Lloyd and Company suggests that the British Transport Commission's decision to fit brakes to all their wagons is of the greatest importance to steel founders. Jointly with the American Brake Shoe Company of New Jersey, U.S.A., F. H. Lloyd have formed Lloyds Brake Shoe Limited " to operate foundry processes and techniques which are being successfully and extensively used " by the American company. Existing plant will be doubled " to keep pace with an ever-growing demand for its products, which now comprise a wide range of high-duty cast irons, nodular cast irons, and carbon and alloy cast steels."

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They Have Problems Too

The industrial techniques of the United States are so often held up as a model of progressiveness that the high degree of self-criticism expressed at the recent Congressional Hearings on Automation and Technical Change, held in Washington by the U.S. Congressional Subcommittee on Economic Stabilisation, must seem a little surprising.

From the testimony of Mr. R. T. Sheen, president of the Instrument Society of America—the journal of which contains a symposium review of the hearing—can be read phrases that seem strangely familiar. " Anything done to enhance the development of scientists and engineers, anything done to enhance the attractiveness of these professions, and anything done to maintain such people in these professions is a step towards solution of our problems." " We don't have to wait for an H-bomb to strike us to lose the cold war. We will lose it soon on the scientific manpower front if we do not bend every possible effort to solve the shortage of technically skilled labor." Military service comes in for sharp criticism from Mr. T. R. Jones, president, Daystrom, Incorporated: " I have been shocked at the amount of time spent in the army in unnecessary manual labor—or even doing nothing at all—by men of superior technical possibilities." It would seem that the problems of skilled manpower are true universals and that army life is much the same, however well cut the uniform.

The growing pains of the new automation industry are also very much in evidence in the review of the hearings: automation, hampered by inadequate appreciation of its capabilities; the need for an efficient information system to prevent duplication, and so wasted effort; difficulties of training old staff to new techniques; lack of skilled personnel at all levels. The fact that modern electronic automation is unreliable, owing to the paradox that the absolutely essential vacuum tube is the least reliable component, was emphasised by Mr. L. N. Ridenour, director of research, missiles systems division, of the Lockheed Aircraft Corporation. The cure would appear to lie ultimately in the use of the new solid-state devices.

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Spring Lull in the U.S.?

There are now signs that the United States boom may be faltering. The first signs of falling confidence were apparent recently in Wall Street, and memories are still fresh enough among Americans to think back to the behaviour of Wall Street in 1929 when the Great Depression began. The interruption of the upward swing of activity is not yet serious. There is some apprehension, however, that a general lack of confidence may develop out of these rather unstable straws in the wind. If that should happen, there could be a general cut-back or delay in investment schedules and this would probably bring the boom to an end.

There have been a few postponements of expansion programmes but no outright cancellations and the postponements have been offset to a large extent by new development projects elsewhere. Employment is high and so are earnings. Government expenditure is on the increase. Even hire-purchase business, although booming, is able to record an adequate level of repayments. On the other hand, profits have been reduced owing to the pressure of costs and savings are not thought to be rising as fast as demand for capital, which spells a potential inflationary situation. The tell-tale of United States prosperity—the stocks of new cars in dealers hands—does not resolve the problem. These stocks have been increasing during February but they are still smaller than in February, 1956. Heavy civil engineering contracts for highway construction have been increasing rapidly but private contracts have declined. There is, in general, a tendency for higher costs to reduce profit margins and hence the reduced attraction of undertaking new commitments. In other words, labour's earnings are tending to rise more quickly than productivity for it is increased wage costs which are exerting pressure.

It would seem that there is going to be a period of uncertainty for the next few weeks. The spring thaw will be awaited with interest for it could bring with it a clearer indication of the trend of industrial activity. All the prophets will be watching to see if the seasonal up-swing of business activity in America is greater or less than the average on such occasions.

CENTRIFUGE FOR MISSILE COMPONENTS

ACCELERATIONS OF 100*g*

Shown in the accompanying illustrations is a centrifuge which can impose alternate positive and negative acceleration loads of 100*g*, designed and built by the Flight Development Establishment of D. Napier and Son, Limited, Luton, Bedfordshire, for testing components and auxiliary services of rockets, guided missiles and high-speed aircraft under simulated flight conditions, such as the violent accelerations reached in missile launching and high rates of manoeuvre during interception.

As a safety precaution the centrifuge is housed in a 25 ft. deep concrete-lined well. The arm of the centrifuge, 19 ft. long, is a welded beam made from two 8 in. steel tubes faced with boiler plate on both top and bottom surfaces and mounted on a vertical hollow shaft driven by a V.8 industrial petrol engine. The shaft consists of two coupled parts; the lower forms the pivot of the centrifuge and runs in roller bearings, the weight of the structure being supported by a thrust bearing on the floor of the well. The upper section runs in ball bearings and transmits the drive to the pivot through a resilient coupling which isolates the centrifuge beam from engine and transmission vibration. Transmission is by multi-belt drive and bevel gearing.

One end of the arm carries an auxiliary turn-table, shown in the upper illustration, mounted on a spindle and connected by spur and bevel gears to the centrifuge transmission system. A clutch enables the turn-table to be rotated under power for the application of alternate positive and negative accelerations, or to be locked in any desired position. The turn-table can have top plates of 10 or 20 in. diameter, but heavy test equipment can be mounted on the centrifuge arm direct if necessary. Lead counterbalance weights are fitted into a welded steel box at the other end of the arm.

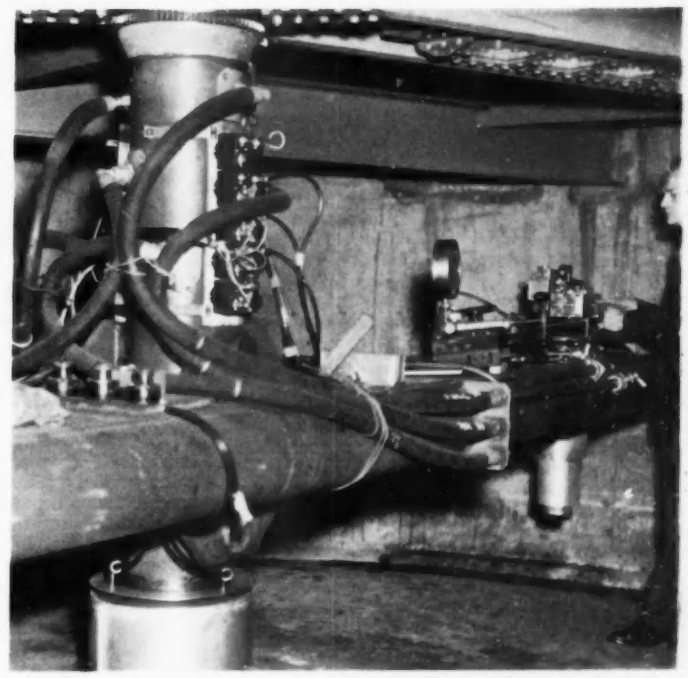
On the roof structure of the centrifuge well is the main-shaft bevel drive which is connected by an enclosed shaft to the power plant situated at the side of the well. The power plant develops 85 b.h.p. and is fitted with a clutch and three-speed gearbox. Low gear gives a centrifuge speed of 0 to 90 r.p.m. (0 to 25*g*), second gear 90 to 200 r.p.m. (25*g* to 100*g*), and high gear 210 r.p.m. for continuous running at 100*g*.

Above the bevel-drive gearbox, an extension to the vertical main shaft accommodates a three-way distributor through which air or fluids may be fed to the equipment under test. Duplicated connecting pipes from the distributor run down the main shaft and along the centrifuge arm to pick-up points adjacent to the auxiliary turn-table. Two of the channels may be used to maintain a return flow system, leaving the third channel for use as a pressure or vacuum line, or for the supply of a non-volatile and expendable fluid which can be jettisoned into the centrifuge well.

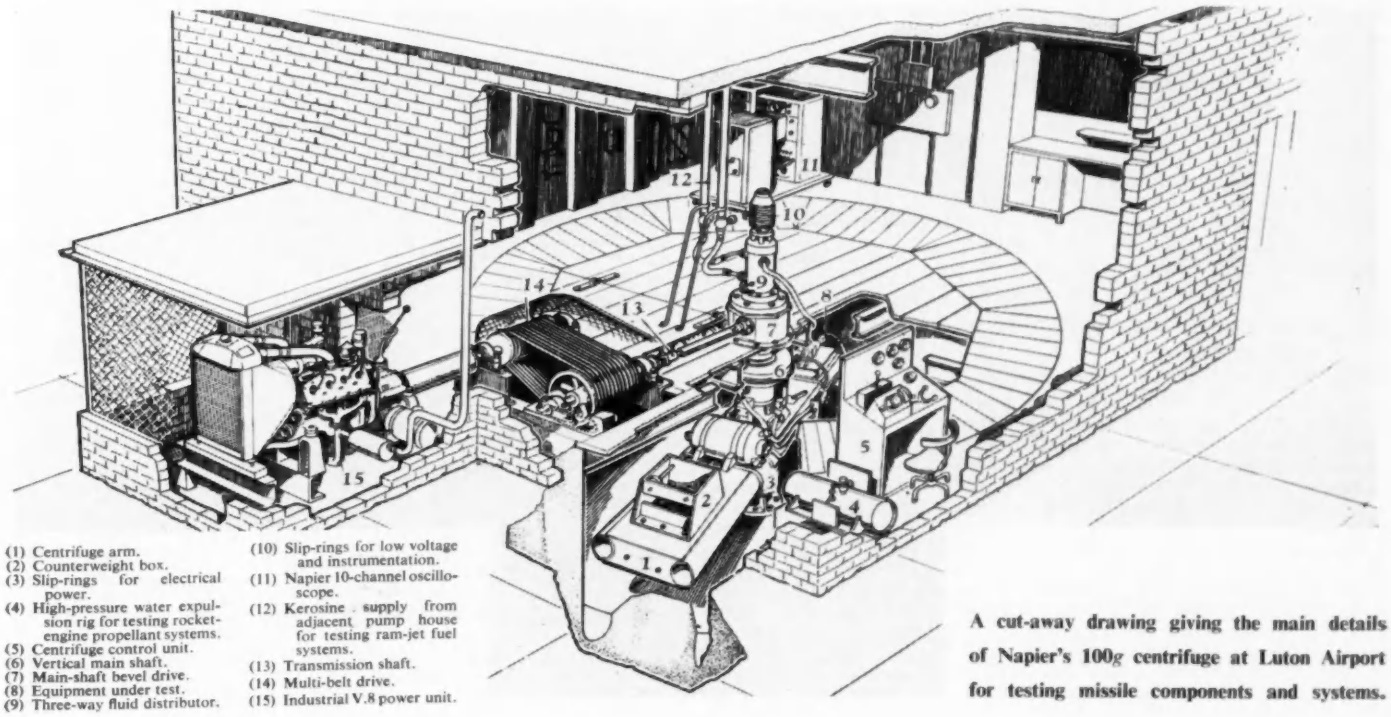
A group of 19 shielded slip-rings for low-voltage electrical supplies and instrumentation purposes are mounted above the fluid distributor. The slip-rings are of polished stainless steel fitted with silver-morganite brushes, leads from the slip-rings passing down the hollow main shaft to a group of oscillators. These may be connected direct to the equipment under test or to a group of 15 similar slip-rings mounted at the base of the auxiliary turn-table. A further group of six slip-rings, situated at the base of the main shaft, supplies electrical power up to 20 amperes at 450 volts.

Air pressure is available from a main supply line; high-altitude conditions are simulated by two vacuum pumps, and nitrogen gas is supplied direct from high-pressure bottles at up to 1,000 lb. per sq. in. Electrical supplies include 24 volt direct-current, 240 volt single-phase and 415 volt three-phase. For oscilloscope recording a 10-channel unit designed and manufactured by Napier is provided.

Water is used as a substitute for the actual propellants when the functioning of rocket-engine components, propellant tanks and control systems is tested, the water being expelled from a 130 gallon tank by high-pressure nitrogen. By this method, very high flow rates are achieved at pressures up to 1,000 lb. per sq. in. Ram-jet fuel system units are supplied with kerosine fuel from a large-capacity circulating system capable of maintaining flow rates of 3,500 gallons per hour at a pressure of 400 lb. per sq. in. for indefinite periods.



Inside the well of the centrifuge, a piece of test equipment is being mounted on an auxiliary turn-table which reverses the direction of the acceleration applied to the test equipment with each revolution of the centrifuge.



(1) Centrifuge arm.
(2) Counterweight box.
(3) Slip-rings for electrical power.
(4) High-pressure water expulsion rig for testing rocket-engine propellant systems.
(5) Centrifuge control unit.
(6) Vertical main shaft.
(7) Main-shaft bevel drive.
(8) Equipment under test.
(9) Three-way fluid distributor.
(10) Slip-rings for low voltage and instrumentation.
(11) Napier 10-channel oscilloscope.
(12) Kerosine supply from adjacent pump house for testing ram-jet fuel systems.
(13) Transmission shaft.
(14) Multi-belt drive.
(15) Industrial V.8 power unit.

A cut-away drawing giving the main details of Napier's 100*g* centrifuge at Luton Airport for testing missile components and systems.

NOW TITANIUM IS CHEAPER : ITS PROPERTIES AND USES

Consider the news that substantial reductions in the price of wrought titanium and titanium-alloy products have been made by Imperial Chemical Industries Limited, the largest producers of the metal in Great Britain. At 19*s.* 6*d.* a lb., raw titanium is selling at the lowest published price in the world, which will undoubtedly tend to widen the applications of the metal and, in all probability, will reawaken the interest of engineers and designers who, while acknowledging the unique properties of the metal, have written it off, up to now, as far too expensive for any ordinary day-to-day purposes. Since the metal was first isolated in the United States on a commercial scale in 1948, the world production of titanium, chiefly in the United States, Great Britain and Japan has grown steadily year by year. Its price has fallen progressively. Dr. Maurice Cook, who succeeded recently to the chairmanship of I.C.I. Limited, Metals Division, said at a conference on "Titanium in the Aircraft Industry," convened by Imperial Chemical Industries Limited, and held in London on February 15, that the total world output of raw titanium had approached the 20,000 tons level in 1956 and might be nearing 30,000 tons in 1957. In the short space of three years, he continued, the price of raw titanium had been nearly halved and, a further encouraging feature was that it might be expected that, by 1960, the price of I.C.I. titanium products generally might be something like half what they were at present. Dr. Cook found no difficulty in visualising a world level of annual output of 100,000 tons in ten years' time and it was conceivable that, eventually, the price of fabricated forms of titanium, on a weight basis, might be about twice that of stainless steel. This approximated to a cost parity by volume.

The gradual increase in the production of titanium, coupled with the steady fall in its price, is strongly reminiscent of what occurred in the aluminium industry; metallurgical history, in fact, appears to be repeating itself. Aluminium, once considered a chemical curiosity, has now become one of the most widely employed of metals. Moreover, there is a further analogy between it and titanium, and that is the existence of abundant workable ores of both metals in many parts of the world. As Dr. Cook pointed out, the supply of titanium in the earth's outer crust is exceeded only by that of aluminium and magnesium.

The engineer may well ask why the metal titanium, discovered so long ago as 1791, remained dormant for such a long period, apart from its occasional use in the form of ferro-titanium in the iron and steel industry, which began in 1895. As Dr. Cook stated, it was not until 1925 that the metal was produced by A. E. Van Arkel, albeit on a small experimental scale, in a state of purity sufficient for an assessment to be made of its properties and of its potential value as an engineering material. Briefly, as now produced, titanium has a density 56 per cent. of that of steel, while its ultimate strength of from 25 to 55 tons per sq. in. can be raised to 70 to 85 tons by alloying. Furthermore, in many applications its corrosion resistance is outstandingly high and superior to that of stainless steel.

EXTRACTION, MELTING AND WORKING

The answer to the question as to why the metal remained a chemical curiosity for something like 130 years is that pure titanium is extremely difficult to isolate on account of its intense reactivity, especially in the molten state, and its affinity for oxygen, nitrogen, carbon and other elements.

It is, in fact, these characteristics of the metal which necessitate the complex, exacting and costly techniques involved in extracting the metal from its ores and its subsequent processing. Most of the titanium produced in the United States is obtained by means of a process devised by W. J. Kroll and first introduced in 1940, but an alternative method has been developed by Imperial Chemical Industries Limited, and is being worked in this country. In this, sodium is used as the reducing agent instead of magnesium but no details regarding the process are available for publication. In Fig. 1, however, is shown part of a plant at Wilton, North Yorkshire, used for the manufacture of raw titanium. The need to cheapen existing extraction techniques or of devising radically new ones was emphasised by several speakers at the conference, and it was stated that in some instances progress was such that items of plant, and, in some cases, a complete piece of apparatus, were scrapped long before their service life was ended in order to make way for a newer and more modern installation.

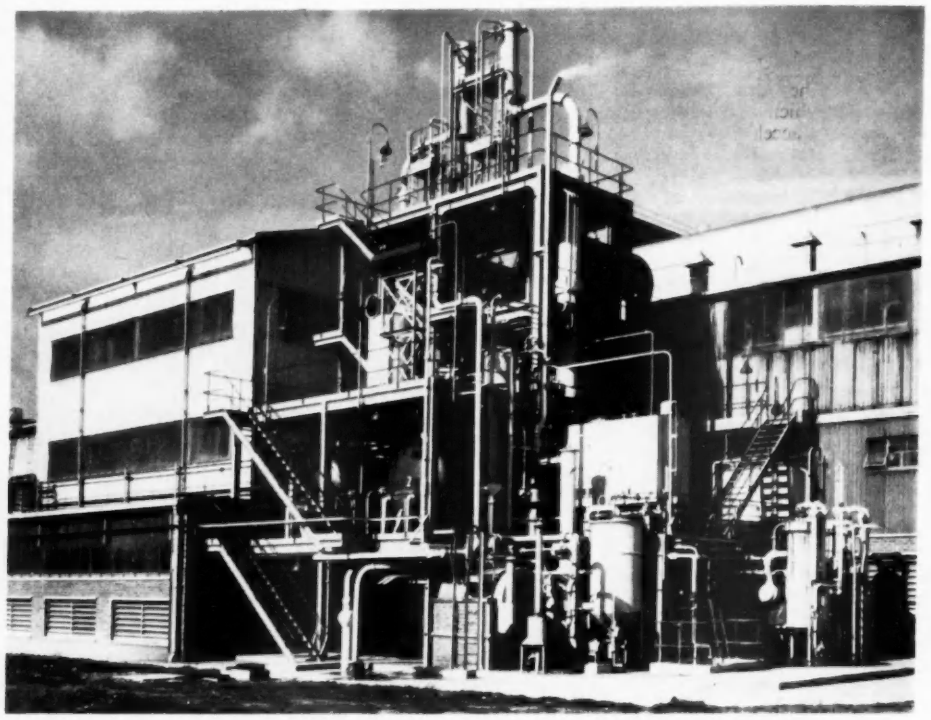


Fig. 1 Part of the plant for manufacturing raw titanium at Wilton, N. Yorkshire.

Thus Mr. St. J. Elstub, C.B.E., former production director, and recently made joint managing director (technical), I.C.I. Limited, Metals Division, said that in October, 1954, the firm were producing 230 lb. ingots by single melting, with graphite electrodes, in argon. Two types of furnaces had become obsolete since then and 800 lb. ingots were being currently produced, all of which were double melted from consumable electrodes, *in vacuo*. By this time next year, 1 ton ingots would be produced as the standard production, with facilities for melting 2 ton ingots as and when required. A view of a titanium melting furnace, showing a water-cooled crucible, is shown in Fig. 2. These developments which mean the writing off of four sets of furnaces in four years, are indeed

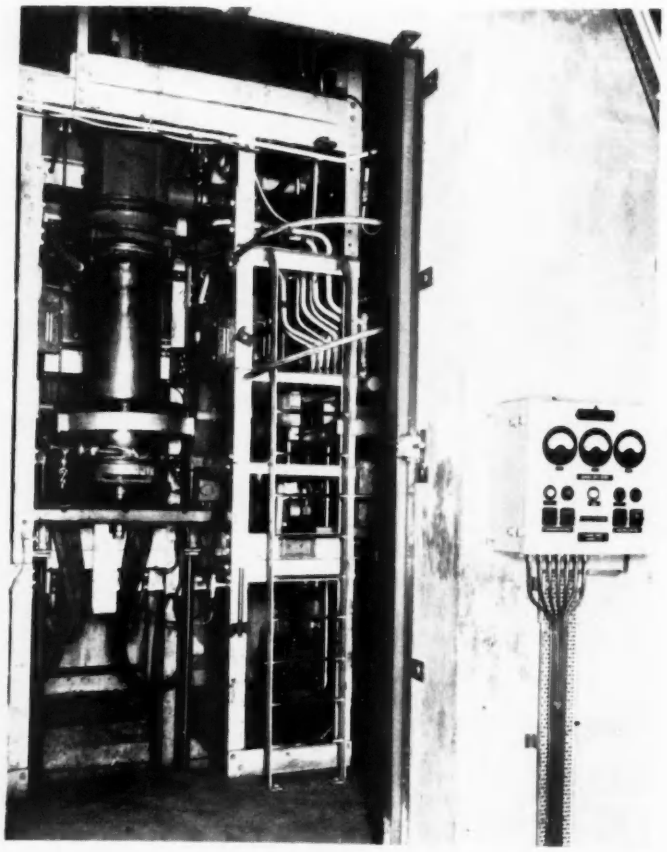


Fig. 2 Titanium melting furnace enclosed in a concrete blast-proof cubicle, showing water-cooled copper crucible and ancillary equipment for vacuum and water cooling.

a far cry from the first commercial production of the metal by the Kroll process. This was in 1948, when from 2 to 3 tons of titanium were made in the United States and sold at a nominal price of 5 dols. a lb. Before leaving the subject of melting it may be added that some difficulties have arisen from safety considerations. As a result of a series of explosions in the United States, all I.C.I. furnaces are now situated in reinforced blast-proof cubicles and operated remotely with all the complications which this involves. The melting furnaces, showing the remote control and blast protection are seen in Fig. 3, and the control panel for the furnaces in Fig. 4.

Up till the present all the wrought forms of titanium have been produced on traditional plant designed for other non-ferrous metals or steel. It is of interest therefore to record the fact that, in October, 1955, the board of Imperial Chemical Industries Limited sanctioned a £3 million scheme for a new rolling-mill plant at Waunarlwydd, South Wales, designed exclusively for the production of titanium sheet and rod. When referring to this project at the conference, Mr. Elstub stated that there was no doubt that the need for such a plant had been appreciated more quickly in this country than in the United States. When the sheet side of the rolling mill (capable of producing sheet 3 ft. and perhaps 4 ft. in width) was completed, by the middle of the present year, and the rod side (for rolling sizes between 5 in. and $\frac{1}{4}$ in. in diameter), by the end of 1957, it would be the first integrated titanium fabrication plant in the world.

TITANIUM ALLOYS

Speaking at the conference on the subject of alloys, Mr. J. R. Crane, production manager, titanium, I.C.I. Metals Division, stated that some of the alloys produced in this country were those which had found favour in the United States. They included the (314A) 4 per cent. aluminium, 4 per cent. manganese alloy; the (318A) 6 per cent. aluminium, 4 per cent. vanadium alloy; and the (317) 5 per cent. aluminium, 2·5 per cent. tin alloy. Others, such as the (314C) 2 per cent. aluminium, 2 per cent. manganese alloy and (371) 13·5 per cent. tin, 2·5 per cent. aluminium alloy, had been developed by the firm to meet specific needs. All these alloys were available in the form of forged billet, bar and slab; rolled rod and bar; drawn rod and wire; shaped bar; extruded and drawn section; and plate.

We understand that apart from welding wire, the main potential usage of small diameter titanium rod is in the field of fasteners, namely, bolts, shear pins and rivets. It appears that relatively little progress has been made in the titanium-alloy rivet field, but as far as bolts are concerned, the Ministry of Supply have announced a programme of work to evaluate the properties of bolts in the 4-4 aluminium-manganese alloy. Further, Guest, Keen and Nettlefolds, Limited, have successfully produced batches of bolts from this alloy and preliminary test results are stated to have been promising.

It is of interest to note that work has been carried out on the development of the extrusion process with some measure of success, but extruded sections are not yet being offered as established products.

In the early days of the use of titanium there was some criticism of the firm's titanium-alloy sheet in respect of flatness and gauge tolerances, but it is emphasised that for some time standards of flatness comparable with alloy-steel sheets have been achieved and, from January 1, 1957, the 2 ft. wide material has been offered to the S500-gauge tolerances, namely, the same as those offered for alloy-steel sheet for use in aircraft.

RESEARCH AND DEVELOPMENT

In the course of an address on the research and development of titanium alloys, Dr. N. P. Inglis, research director, I.C.I. Metals Division, gave some recent results on the fatigue and notch-fatigue characteristics and the creep or long-term strength properties of various titanium alloys at elevated temperatures. He said that throughout all the fatigue-testing work carried out, the conclusion had clearly emerged that the fatigue strength of titanium and its alloys was high, the ratio of fatigue strength, under complete reversals, to the ultimate strength, being 0·5 for commercially pure titanium. The ratio rose to 0·6, and even slightly higher, for several alloys. In this respect, titanium and its alloys were far closer to steel than they were to light alloys and other non-ferrous metals. Tests at elevated temperatures had shown that the high ratio of fatigue strength to ultimate strength, observed at normal temperature, was preserved at these higher temperatures.

In an endeavour to compare the notch fatigue sensitivity of titanium with that of metals which had a longer established use for engineering components, specimens with different notches had been tested under both reversed bending stresses and reversed direct stresses. This work was not yet complete, but, as far as it had gone, the broad general conclusion was that titanium was not unduly peculiar as regards notch-sensitivity effects.

CORROSION AND CREEP PROPERTIES

The corrosion-fatigue performance of titanium had been proved to be outstandingly good. In fact, in one set of tests with commercially-pure titanium, where 3 per cent. sodium chloride solution had been used as the corroding medium, the fatigue strength was found to be slightly higher than in air. This slight, but definite, increase was presumably due to the cooling effect of the corroding medium. No similar result had been found with any others of the relatively large number of metals tested in this manner.

Of all the materials considered, No. 371, the 13·5 per cent. tin, 2·5 per cent. aluminium alloy gave the best creep charactetistics at temperatures between 400 and 500 deg. C. Recent research on this alloy had shown that under high stresses the creep characteristics obtained were very dependent on heat treatment, and the poorest creep characteristics were given by material in the fully-annealed condition. In practice the most satisfactory properties were given by a treatment involving quenching from 1,100 deg. C., followed by reheating to 800 deg. C., and again quenching. Dr. Inglis emphasised that the importance of this heat treatment on creep characteristics applied only at high stresses. Results obtained had demonstrated fully the importance of heat treatment on the creep characteristics at 400 deg. C., with a test stress of 35 tons per sq. in., and the relative unimportance of the heat treatment at stresses of 25 tons per sq. in. at the same temperature.

The principal item of research in the alloy field at present was an intensive search for a relatively-soft alloy which could be hardened very considerably by heat treatment. The target aimed at was for a material having a tensile strength of 40 tons per sq. in. in the annealed condition, rising to, say, 80 tons per sq. in. after suitable heat-treatment, plus the additional requirement of reasonable load-carrying ability at between 300 and 400 deg. C. This, it must be repeated, is the objective set before investigators, and not yet the attainment.

CURRENT APPLICATIONS

During the course of the conference it was announced that, of the semi-fabricated titanium sold by the company during 1956, a rough analysis gave the following categories. Some 40 per cent. of the material had been supplied in rod form for the manufacture of compressor blades; 20 per cent. had been supplied as commercially-pure sheet for use in fire walls; a further 20 per cent. commercially-pure sheet had been employed for exhaust and jet pipe shrouds; 5 per cent. had been supplied in the form of titanium-alloy billet for the production of discs and spacers and 5 per cent. in the form of bar for small forgings, fabrications and other purposes. This, it will be found, adds up to

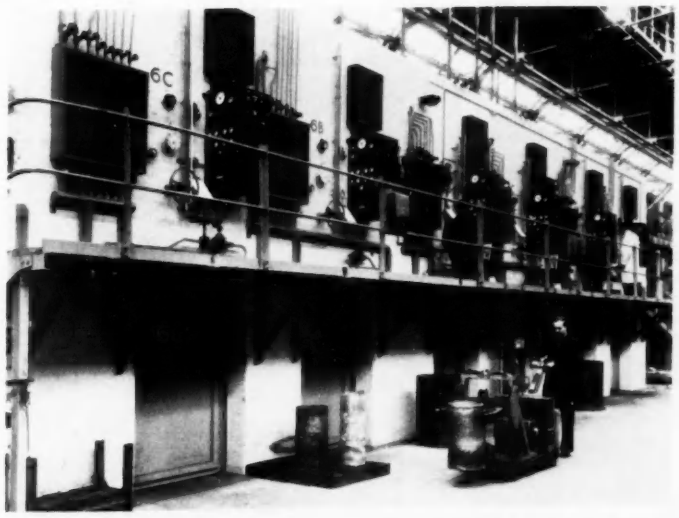


Fig. 3 Group of six furnaces for melting titanium ingots of approximately 800 lb. weight, showing provision for first and second melt, remote control platform and blast protection.

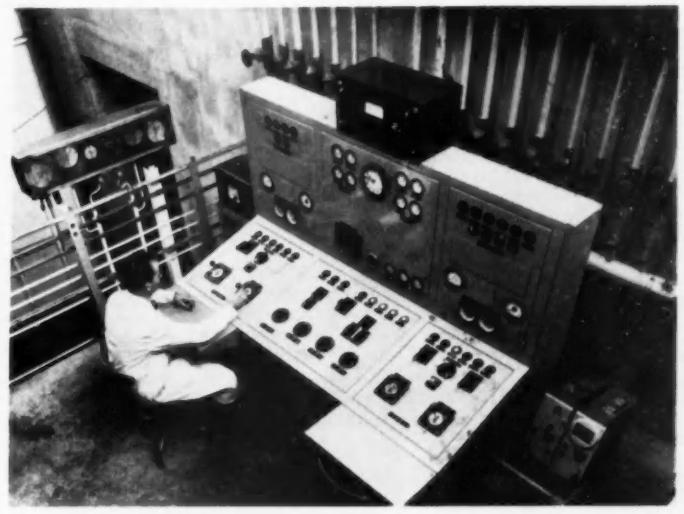


Fig. 4 Control desk for the remote operation of titanium furnaces at the I.C.I. Metals Division works in Birmingham. From this desk the progress of the melt can be observed by means of instruments and closed-circuit television.

90, and not 100, but it was pointed out that the remaining applications were difficult to classify and could only be described as miscellaneous uses.

GALLING OF TITANIUM

The old trouble of the galling and tearing of titanium when in sliding motion against itself and other metals was not very much discussed at the conference, but it was stated that the problem of fretting corrosion, to which several questioners drew attention, would be investigated. The tendency of titanium to gall and stick when in contact with itself, Dr. Inglis pointed out, made the metal unsuitable for the production of such components as gears, for helicopters or other aircraft.

The final impression left was that this matter of galling and seizing was not perhaps so serious as it was some time ago and, in this connection, Mr. R. L. Preece, of the technical service department, I.C.I. Metals Division, stated that while problems associated with the galling of titanium were holding back some applications, there was much hope that various surface treatments, such as oxidation, anodising, cyaniding, electroplating and chemical deposition could help in this direction.

Improving Gas Turbine Performance—3

COOLING TURBINE BLADES

The liquid cooling of turbine blades has been the subject of an extensive research programme carried out by the Department of Mechanical Engineering of King's College in the University of Durham, and the article published below represents a part of this work. *In a previous article published in* ENGINEERING ***on March 1, page 272, by a member of the same department, attention was drawn to the effect of high operating temperatures on gas-turbine performance; the present paper discusses an approach by which such temperatures can be achieved in practice.***

HEAT TRANSFER CHARACTERISTICS OF A LIQUID METAL IN THE CLOSED THERMOSYPHON

By F. J. Bayley, M.SC., PH.D., A.M.I.MECH.E,* *and N. Bell* B.SC.*

Summary

This paper presents an account of an experimental investigation concerning the operation of the thermosyphon system of heat transfer; mercury was used as the internal coolant. Quantities of this liquid metal were enclosed in the hollow spokes of a wheel rotated at speeds up to 1,500 r.p.m.; the inner halves of the wheel passed through a cold air stream and the outer halves through hot gas from a combustion chamber. The variation in the observed rates of heat transfer suggests that, owing to the restriction placed upon convective motion in the liquid by the narrow confines of the thermosyphon elements, the only significant transfer of heat between the hot and cold sides resulted from evaporation and condensation. Further and more important, it was found that under the conditions of this experimental investigation the returning stream of condensate from the cooled ends of the thermosyphon elements contributed significantly to the heat transfer process.

Introduction

It is now becoming generally accepted that a worthwhile improvement in the performance of internal combustion turbines will only be possible by increasing the maximum gas temperature to such a level as to make inevitable liquid cooling of the turbine rotor blades. Air, the logical coolant for gas turbines, because of its low thermal capacity and conductivity allows only a limited increase in maximum temperature beyond that possible in uncooled engines, although air-cooling systems have the great advantage of requiring a minimum of mechanical complication. It is for this reason, probably, that until recently most research and development has been concerned with the use of air for cooling turbine blading, for the "plumbing" difficulties, as they have been termed, of dealing with liquids in the inevitably confined spaces of high-speed turbine rotors are formidable.

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BENEFITS OF CLOSED SYSTEM

The closed thermosyphon system, in which a quantity of coolant is enclosed within each blade to act as a conveyor of heat to a secondary coolant flowing over the root, enables some of the difficulties of liquid cooling to be avoided. For instance, it is not necessary to provide continuous flow passages within the blade section, as with forced-convection systems, nor are the blades themselves subjected to the hydrostatic forces corresponding to a column of liquid of height almost equal to the radius of the rotor and acted upon by centrifugal accelerations of up to 30,000 *g*. Further, and of great importance, since the liquid is enclosed within the cooling passages in the blades, these are not liable to blockage by centrifugal deposition of solid impurities in the main circulating coolant, a problem present with all open liquid-cooling systems.

Another great advantage of the closed thermosyphon is that it makes possible a wider choice of coolant, since liquids which by their toxic or chemically reactive nature are impracticable in open systems can be sealed into the blades and used in conjunction with a more conventional external coolant at the root. This is an important factor in turbine cooling applications of the thermosyphon because water, the obvious choice of liquid, while it has many advantages—namely high latent heat, good thermal conductivity, chemical inertness and abundance, among others—has the one great disadvantage that its critical temperature is only 704 deg. F. (373 deg. C.). This means that turbine blades in which water is used as the coolant must either operate at temperatures much less than the materials available will withstand, with the thermodynamic penalties which this undercooling implies, or, alternatively, the whole cooling system must be pressurised to at least 3,200 lb. per sq. in., and evaporative methods of heat transfer, with their many advantages, ruled out. Unfortunately, there are few liquids known which have critical temperatures higher than that of water and in practice, for purposes of turbine cooling, the only alternatives to water are the liquid metals, the properties of which are relatively unknown.

In this paper some experiments carried out in the Stephenson Engineering Laboratories of the University of Durham are briefly described, in which the heat transfer characteristics of liquid metals in the closed thermosyphon have been investigated. Although the results obtained are provisional and of a qualitative nature it is thought that the trends which they indicate are sufficiently unexpected to be of interest to others who are engaged in or are contemplating work of a similar nature in connection with the cooling of gas turbine blades or other problems for which liquid metals are particularly useful.

Apparatus and Procedure

The apparatus used for the experiments described here was originally designed and operated by Dr. Henry Cohen, and is described in detail by Cohen and Bayley (1955). Briefly, the heat transferring apparatus (Fig. 1) consists of a wheel which can be rotated at speeds up to 2,000 r.p.m. and which has 24 hollow spokes in which the coolant to be tested can be placed. During part of each revolution the outer halves of the spokes pass through a stream of hot gas from a gas-turbine combustion chamber, while the inner halves similarly pass through a stream of air at about room temperature supplied from a blower which also delivers air to the combustion chamber. The rise in temperature of the air in passing through the apparatus is accurately measured and from its rate of flow the amount of heat transferred by the thermosyphon action

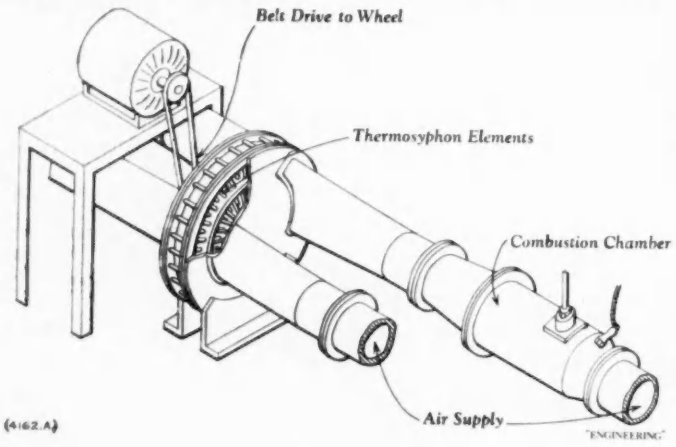

Fig. 1 (left) Experimental apparatus for determining the rate of heat transfer in a rotating thermosyphon. The spokes of the wheel correspond to the hollow blades of a gas turbine in which liquid metal is sealed.

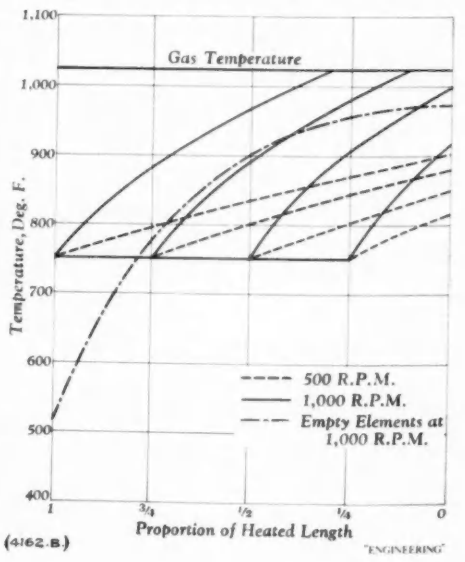

Fig. 2 (right) Saturation temperature distribution in rotating elements at two speeds—500 and 1,000 r.p.m. Cooling is effected by evaporation and condensation.

of the liquid within the spokes or elements can be determined. No attempt was made to measure the temperatures of the rotating elements and accordingly the apparatus should be regarded as giving a qualitative or comparative picture of the different thermosyphon arrangements tested, rather than a detailed quantitative analysis of the heat-transfer processes occurring. For this latter purpose a far more elaborate and costly apparatus would be necessary.

LIQUID METAL IN HOLLOW SPOKES

For the tests described here, mercury, the most readily obtainable of the liquid metals and the one of which the physical properties are best known, has been used as the coolant. Amounts sufficient to fill one-quarter, one-half, three-quarters and the whole of the heated length were put into the hollow spokes with a graduated burette. Measurements of the rate of heat flow from the gas stream to the cold air have been made at speeds of 500, 1,000 and 1,500 r.p.m., corresponding to mean centrifugal accelerations in the heated ends of the thermosyphon of 49, 196 and 440 times the acceleration due to gravity. To obtain adequate rates of heat flow the gas temperature has been kept constant throughout the test series at 1,025 deg. F. (552 deg. C.), which is considerably above the temperature at which the apparatus was designed to operate. Consequently, considerable mechanical development has been necessary, mainly to overcome the problem of thermal distortion.

The procedure adopted for the tests has closely followed that developed by Cohen. Tests were first run to determine at each speed the rate of heat transfer by all means other than through the thermosyphon elements. Then followed, for comparative purposes, experiments to measure the rates of heat flow with empty elements, before the appropriate quantities of mercury were inserted for the main investigation to begin. Before and after each series of tests the thermosyphon elements were weighed to ensure that the required quantity of mercury had been put into the elements and to check that the sealing system had remained tight.

Results

The rates of heat flow in B.Th.U. per second through the 24 thermosyphon elements observed during the tests with the different quantities of mercury and at the three speeds are given in Table I.

At each speed it is seen that the insertion of the first small quantity of mercury caused the rate of heat flow from the heated to the cooled ends of the thermosyphon elements to increase, as would be expected, above the values observed with no internal coolant. At 500 r p.m. increasing the quantity of mercury in the elements led to no substantial change in the rate of heat flow until the heated length was full. At the two higher speeds the strange result was obtained that the rates of heat flow fell with the addition of more coolant, to less than that observed with the empty elements, until the heated length was completely submerged.

Mechanism of Heat Transfer Process

These unexpected results which, it will be shown, are of great significance in the application of the thermosyphon to turbine cooling, can be explained by reference to the modes of heat transfer which can obtain in liquid-filled elements. In the tests described in this article the only means whereby heat could be transferred through the coolant to the cold ends was by evaporation and condensation of the mercury, or by metallic conduction along the tube walls.

CONVECTION AND EVAPORATION

It would be expected that most of the vapour would form at the free surface of the liquid, the latent heat being supplied by convective motion arising from buoyancy forces in the centrifugal acceleration field caused by rotation of the wheel. If, however, it is assumed that heat transfer takes place only by boiling in the liquid column, then, in view of the very high coefficients associated with this mode of heat transfer, the walls of each element would take up a temperature distribution following closely the saturation temperatures of the coolant at the prevailing hydrostatic pressures. Fig. 2 shows the variation in saturation temperature along the liquid column in the heated ends of each element for the quantities of mercury tested at the two speeds, 500 and 1,000 r.p.m. Similar, but steeper, lines are obtained for conditions at 1,500 r.p.m., but are not shown to avoid further confusing the figure. The pressure at each radius, r, due to the column of mercury was calculated from the expression $\int_{r_s}^{r} \sigma\omega^2 r dr$, where r_s is the radius of the free liquid surface, ω the angular velocity of rotation and σ the density of mercury. The pressure above the surface would depend upon the largely unknown conditions which prevailed at the cooled end of this completely

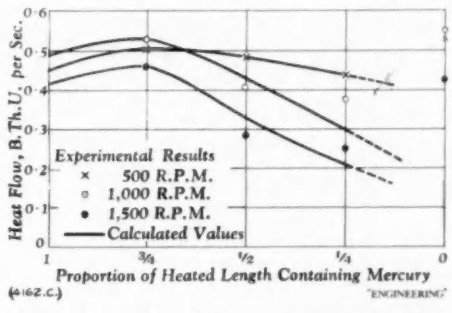

Fig. 3 Comparison between experimental values of heat-flow rate and those calculated on the assumption of heat transfer by evaporation from the curves of Fig. 2.

enclosed system. If the mercury vapour diffused throughout the air enclosed in the elements, the additional partial pressure of this gas would have raised the total internal pressure above the saturation pressure and prevented boiling (not evaporation). It is more likely, however, that the mercury vapour displaced the lighter air to the inner ends of the cooled region of each thermosyphon element so that the vapour pressure was then equal to the total pressure in the system. The exact value of this pressure would depend upon the unknown internal and external heat transfer coefficients at the cooled ends of the elements, but within wide limits, the argument which follows is unaffected, qualitatively at least, by the saturation pressure. For the purposes of illustration it has been assumed constant at 30 lb. per sq. in., a mean figure consistent with the conditions of the tests.

Those parts of the wall of each element above the surface of the liquid column will have been in contact with either the vapour of the internal coolant or the condensate returning from the externally cooled ends of the thermosyphon. In the former case, cooling of the wall above the liquid column would have been negligible, and increasing the quantity of mercury would have increased the rate of heat transfer, contrary to the observations. In the second case the wall temperature would be substantially that corresponding to the saturation temperature of the mercury at the free surface, with a process of heat transfer by evaporation from a liquid film similar to that described in detail for water in the closed thermosyphon by Cohen and Bayley (1955).

The rates of heat flow from the heated ends of the element to the internal coolant, with the assumption that the only significant mode of heat flow is by evaporation, are represented by the areas between the lines corresponding to the distribution of saturation pressure at the different conditions tested and the horizontal line representing the constant gas temperature. Up to the condition at which the heated length is completely submerged in mercury, these areas are found to vary with filling quantity in a manner which almost exactly follows the observed variation in the rate of heat transfer through the

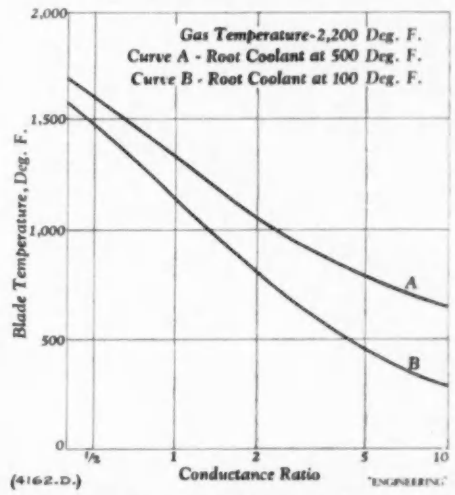

Fig. 4 Effect of conductance ratio on turbine blade temperature. Much less severe heat-transfer rates are required at the blade root when higher operating temperatures are possible.

thermosyphon elements, as is demonstrated in Fig. 3. In this figure the rates of heat transfer calculated from the curves of coolant saturation temperature and the heat transfer coefficient measured with the elements one quarter full are compared with the experimental results.

TABLE I.—*Experimental results for heat flow in thermosyphon elements*

Elements, ⅜ in. o.d., ¼ in. bore, 2¼ in. heated length, 3¼ in. cooled length.

Filling quantity	Speed, r.p.m.	Net heat flow, B.Th.U. per sec.
Empty ..	500	0·451
	1,000	0·485
	1,500	0·414
Heated end ¼ full	500	0·504
	1,000	0·528
	1,500	0·461
Heated end ½ full	500	0·481
	1,000	0·409
	1,500	0 283
Heated end ¾ full	500	0·450
	1,000	0·376
	1,500	0·254
Heated end full	500	0·531
	1,000	0·552
	1,500	0·428

VAPOUR PRESSURE

Better agreement between the calculated and measured results is obtained if the temperature-area integral for that part of the heated length above the liquid column is multiplied by a factor of 0·8. This factor can readily be accounted for by the observation by Cohen and Bayley (*loc. cit.*) in experiments with water in a static thermosyphon, that the returning condensate film did not completely cover the wall of the thermosyphon tube, an effect which would probably be increased in the present apparatus by the Coriolis forces acting. These tend to direct the film away from the leading surfaces, thus causing local cooling failure in these regions. Equally, however, the factor could be accounted for by variations in the internal vapour pressure which has been assumed constant, but which almost certainly is dependent upon the rate of heat flow.

In either case, however, the qualitative results, such as the decrease in the rate of heat flow observed under some conditions when the speed was raised or the quantity of internal coolant increased, are unaccountable unless the assumption is made that heat transfer to the internal coolant occurs when the heated length is less than full only by evaporation over the whole liquid column, and further, that the walls above the liquid surface are cooled by a film or series of rivulets of returning condensate and thereby contribute significantly to the heat-transfer process.

The increased rates of heat flow observed in

the two test series in which the heated lengths of the thermosyphon elements were submerged in mercury can be explained by reference to the temperature distribution along the walls of the empty elements rotating at 1,000 r.p.m. drawn in Fig. 2. This curve was calculated from the measured rate of heat flow and the hot gas-to-elements heat-transfer coefficient deduced from the earlier tests referred to above, and is seen to lie below the saturation temperature curve drawn for the appropriate rotational speed. Thus when the heated length is submerged it is clear that no evaporation will occur and temperature gradients in the elements, which were previously evened out above the liquid column by the condensate and vapour of the mercury which only partly filled the heated length, are created which contribute significantly to the rate of heat flow.

The severe temperature gradients along the columns of mercury in the closed thermosyphon elements of the apparatus here described, which appear to be consistent with the experimental results obtained, may need some justification since it would be expected, at first sight, that convective buoyancy forces due to the centrifugal acceleration in the rotating apparatus would even them out. For instance, if theoretical data on heat transfer by free convection in liquid metals (Bayley, 1955) is applied to the conditions of the tests reported here it is found that the rate of heat flow observed in the test with the elements half-full at 1,500 r.p.m. would be achieved with a mean temperature difference of only 1·8 deg. F. (1 deg. C.) between the inner walls and the coolant. At this condition, however, substitution of the relevant values of the properties concerned into the expression for the boundary layer thickness which is also derived in the theoretical paper cited, shows this to be about 0·26 in. at the free liquid surface, which is more than the internal diameter of the thermosyphon elements. A similar result is obtained for the other tests at the lower speeds. It is, therefore, clear that the geometry of the thermosyphon system will impose a severe restriction upon the rate of free convection circulation of the internal coolant, sufficient apparently, according to the results reported here, almost to damp out convective motion altogether.

Conclusions

The two significant findings of the experiments described in this article are, first, the evidence of a very severe restriction upon the convective circulation rate in the closed thermosyphon containing a liquid metal—mercury. Second, and more important, the evidence that mercury acts as a coolant by running over the heated surfaces of the elements as a film in the manner in which water was observed to behave in the experiments reported by Cohen and Bayley (1955).

CIRCULATION AND SPEED

The first of these two main conclusions is of less interest because the conditions in the rotary apparatus tested are much less favourable for the setting-up of a stable free convection circulation than will be those in a turbine, for which the heat-transfer system is finally intended. Thus, the maximum centrifugal acceleration achieved in the tests described here was 440g, whereas, as has been pointed out, values of up to 30,000g are quite likely in a gas-turbine rotor. With their higher centrifugal accelerations the boundary layers for a given rate of free convection heat transfer tend to be much thinner, and consequently the restriction on the circulation is reduced. In the discussion on the previous paper by Cohen and Bayley (1955), Dr. T. W. F. Brown gives details of results obtained on a rotating apparatus at Pametrada which suggests that at very high rotational speeds liquid metals can provide adequate rates of heat transfer in the closed thermosyphon by free convection alone with no change of phase.

The importance of the second main finding—that mercury appears to act effectively as a coolant in the form of an evaporating film—is that it suggests that the thermodynamic advantages of this fluid as a coolant for turbine blades may be utilised without the mechanical disadvantages normally resulting from its high density. If just sufficient mercury were sealed into a hollow turbine blade to ensure a complete film of liquid over the internal surfaces no hydrostatic forces would result and the only additional blade stresses resulting from the presence of the coolant would be those due to the vapour pressure. With mercury this need not be a serious factor to be taken into account, since for instance an operating blade temperature of 1,000 deg. F. (533 deg. C.) could be employed with an internal pressure of only 180 lb. per sq. in. The thermodynamic advantages of mercury as a coolant, in fact, lie in the possibility that it enables the whole range of practicable blade working temperatures to be utilised, and the particular value to be chosen from considerations quite unaffected by the internal heat-transfer characteristics of the cooling system. Thus with evaporation as the mode of heat transfer within the turbine blades, the internal resistance to heat flow may be considered negligible so that design of the cooling system is reduced to the achievement of a suitable value of the conductance ratio, defined as

$$\frac{\text{heat-transfer coefficient} \times \text{surface area for heat extraction (at blade root)}}{\text{heat-transfer coefficient} \times \text{surface area for heat input (at blade span)}}$$

Fig. 4 shows how this parameter affects blade operating temperatures, and indicates the much less severe heat transfer rates required at the blade root when higher operating temperatures are possible than are necessary if undercooling is made inevitable by the characteristics of the many alternative liquid coolants which can be utilised in a thermosyphon system.

MERCURY COOLANT PREFERRED

It is, therefore, clear that many advantages will result if mercury can be used as an internal blade coolant on the evaporating film principle previously observed to be possible with water. While the results reported in this article suggest that mercury can operate in this way, the conservative conditions of the apparatus used for the tests described, when compared with those of turbine operation do not enable a final definite conclusion to be drawn on this point. The urgent need now is for experimental confirmation, or otherwise, from a more advanced and elaborate apparatus than is possible in a University Department.

Acknowledgment

The Authors are indebted to Professor A. F. Burstall, Director of the Stephenson Engineering Laboratories of the University of Durham for his encouragement and assistance in carrying out the work reported in this article.

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HEAT PUMP INGENUITY

Shop-keepers everywhere have long known that it is greatly to their advantage to keep the customers warm and happy. A customer who does not have to hurry through a building because he is cold is more likely to stop and look at the goods displayed, and be tempted thereby to purchase. Consequently, heating systems for shops have long been a standard installation. Naturally, the larger the store, the more complex the system has to be, and when, as in Minneapolis, the temperature range experienced between summer and winter is very large, an adequate peak heating system must also be large.

In the Southdale shopping centre, use has been made of that highly controversial method, the heat pump. The whole Centre is indoors, and the stores are arranged around a huge roofed court. There are actually about 70 shops, and the centre has a gross floor space of about 800,000 sq. ft. under one roof. Advantage has been taken by Victor Gruen and Associates, the designers of the system, of all the possible economies available with the heat pump, but it was primarily chosen because of capital savings, thereby in complete contrast to installations in this country, where capital cost (certainly for domestic equipment) is so high as to require a very long-term policy of cost recovery. The heat pump can be used in a reverse cycle to provide cooling in hot weather. That is generally known, but the system at Southdale also takes advantage of summer heat to provide winter heat, by a vast system of water storage; thus the heat generated in summer by customers, store personnel and electric lights, will be picked up by the air conditioning system, and transferred by the heat pump to underground water stores, from which next winter, the same pump will withdraw the heat and return it to the building.

Air is circulated by fans in a penthouse, and is either cooled or warmed to 75 deg. F. The conditioned air passes into the central garden court, and other fans draw it through each of the shops, and then to the basement storage areas where truck fumes are extracted. Another fan pulls it to the roof where it blows away. Three 420 ft. deep wells were sunk below the store, where the water is at a constant 50 deg. F. and in summer water will be pumped to the penthouse to pre-cool the incoming air and will thereby be warmed to about 60 deg. F.; it then passes through the central condenser unit of the air conditioning system, which raises it to 75 deg. F., and then to the separate stores producing a final temperature of 90 deg. F. Some of the water is then pumped back to the roof, to deflect the sun's rays, and the rest goes back to the penthouse to cool the gas engines used in the air conditioning system. The water has then reached a temperature of 110 deg. F. and is returned to one of the wells. This hot water will form the heat sump for winter operation of the heat pump. It is estimated that it will take about three years to heat the ground in the storage area sufficiently to keep the water at 90 deg. F. If you build big, you must plan big, and this is certainly a big test for a heat pump system.

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INTERNATIONAL METALLURGICAL MEETING IN LONDON

The Associazione Italiana di Metallurgia, the Association Suisse pour l'Essai des Matériaux, and the Société Suisse des Constructeurs de Machines have accepted invitations from the Council of the Institute of Metals to hold a joint spring meeting in London with the Institute from April 29 until May 3. After the meeting in London, delegates of the Italian and Swiss societies will leave for visits in the Birmingham, Sheffield and South Wales areas.

The opening ceremony of the meeting will be held at the Royal Institution, Albemarle-street, London, W.1, at 6.30 p.m., on Monday, April 29, and will be followed by the May Lecture. The annual meeting of the Institute, at which Dr. L. B. Pfeil, O.B.E., F.R.S., will deliver his presidential address, will commence at 9.30 a.m. on Tuesday, April 30, at Church House, Westminster, London, S.W.1. Here an afternoon session, and morning and afternoon sessions on Wednesday, May 1, for the discussion of papers, will also be held. The final business session of the meeting will take place at the Institute headquarters, 17, Belgrave-square, London, S.W.1, at 10 a.m. on Thursday, May 2. In the evening a banquet will be held at Grosvenor House, Park-lane, W.1, at which delegates and ladies of the Italian and Swiss societies will be the guests of the Institute.

COMPONENTS AND ASSEMBLIES TO ORDER

SEVEN-BAY PRODUCTION SHOP

The new engineering works of Beans Industries, Limited, Tipton, are adjacent to the Company's two grey iron foundries, described in last week's issue of ENGINEERING. They have an area of 250,000 sq. ft. under a single roof, and consist of seven production bays, each 50 ft. wide and 630 ft. long, with a 60 ft. wide receiving and materials stores bay at right angles to the production area, and running across its whole width. The building is of fabricated tubular construction throughout. As the products being handled are mostly of small or medium size, overhead travelling cranes are only needed in two parts of the works, the receiving and dispatch sections, but monorails with electric or manual lifting blocks are provided at all necessary points. Transport of most of the work in progress is by box pallet and fork-lift truck.

BATCH PRODUCTION

The works are laid out for the batch production of engineering components and assemblies in the light and medium classes, and as a consequence the machines are mostly grouped according to type. The exception is a flow line for producing tractor transmission cases; in this instance the machines are arranged according to the sequence of operations. There is a fully-equipped tool room, and a jig and tool drawing office is attached to the works, which can thus design, manufacture and maintain all the jigs, tools and fixtures required in the production sections.

The products of the works are varied, and change from time to time. The transmission case already mentioned, which is for the large model 745 Massey-Harris-Ferguson tractor, and comprises a complete gearbox and back axle assembly, is a typical product, the components for which are all made either in the engineering works or the Company's foundries. A smaller product which is assembled in the same section of the works as the tractor transmission is an epicyclic gearbox, also for tractor work, but in this instance for a smaller tractor. Final and auxiliary drives for heavy fighting vehicles also pass through the machining and assembly sections of the works. Other examples of work in normal production are parts for agricultural machinery, and assemblies made from bar stock and forgings for aluminium reduction furnaces.

RAW MATERIALS RECEPTION

The raw materials consist of castings from the Company's foundries, and bar stock and forgings from outside suppliers. All these materials are received by road, and there are three unloading docks for road vehicles in the reception and stores bay. A 5 ton overhead electric crane runs the whole length of this bay, which is equipped with storage racks for bar stock and cold saws for stock-cutting as required. Part of the bay is reserved as a work-issue area, in which castings and other raw materials are marshalled ready for distribution to the machines. A small section of this bay is laid out for swarf collection and disposal; otherwise the bay is solely for receiving and storing materials. All finished goods pass out of the opposite end of the works.

FLOW LINE FOR TRANSMISSIONS

Two of the seven bays leading off the reception and storage bay are used for special purposes, while the remaining five bays are devoted to machine groups. In the first of the special-purpose bays, which is bounded on one side by the outside wall of the works, there is the transmission machining line and the assembly area. In the second bay, on the opposite side of the factory building, there are the tool room and heat treatment department.

Tractor transmission manufacture starts with the box castings, which are passed along a line of machines, principally vertical and horizontal millers, horizontal borers and radial drilling machines, served by 10 cwt. electric hoists on a monorail running the whole length of the machining line. Machined boxes pass off the end of the line to the assembly area, where they are mounted temporarily on wheeled vehicles for assembly purposes. Gears, shafts and other components are drawn from the finished-part stores, which adjoin the assembly area. At the end of the assembly area there are spray-painting facilities, and finally there is a section devoted to dispatch. This has direct road access, and is served by a 5 ton overhead electric travelling crane.

GROUPED MACHINES

In the bays lying parallel with the flow line and assembly area there are grouped all the production machines, which can be divided, broadly, into the following sections: capstan lathes, centre lathes, automatics, copying lathes, vertical boring and turning machines, horizontal borers, millers, drillers, grinders, gear shaping and hobbing machines, and spiral bevel gear hobbing machines. The range of machine capacities is sufficient to cover all light and medium machining needs. Capstan lathes, for example, range from $\frac{3}{16}$ in. minimum diameter bar lathes, to chucking machines which will swing 20 in. diameter over the cross-slide. Similarly, centre lathes are available to take up to 24 in. diameter by 8 ft. between centres, and the copying lathes, which are Fischer machines, will swing up to 18 in. In the milling machine group the machines range up to a Koliman plano-miller with a table working surface of 106 in. by 35 in. Drilling machines are in various sizes from single-spindle sensitive machines to 6 ft. radials. Internal, external and surface grinding equipment is in line with the other production machines.

Gear cutting equipment comprises a group of Fellows and Sykes gear shapers, which will cut gears up to 40 in. outside diameter and $2\frac{1}{2}$ D.P., hobbing machines of various makes, with capacities up to 18 in. outside diameter, Gleason straight bevel gear shapers, and a range of gear testing machines.

Spiral bevel gear hobbing is carried out on a group of six Klingelnberg machines, cutting from 2 to 8 module, and also capable of producing hypoid gears. Three of the machines are normally used for cutting pinions, while the other three are for crown wheels only. The Klingelnberg group is complete with a pair of Klingelnberg lapping machines, and a noise tester of the same make, which is housed in a sound-proof cabinet, and used for checking backlash, marking, and running centres, as well as noise.

All finished components from the various machine groups pass to a final inspection department, which adjoins the stores previously mentioned. From here the components are drawn off as required by the assembly area or, alternatively, withdrawn for dispatch direct to customers.

HEAT TREATMENT AND TOOL MAKING

For heat treatment, both of products and of tools, there is a range of equipment located at the end of the tool room bay. This section of the works contains six Birlec electric furnaces, each with a hearth 3 ft. 6 in. by 7 ft., which are used for normalising and case hardening. The furnaces are complete with charger, and roller conveyors leading to and from the charger track to a pot-filling and emptying area. Seven smaller Birlec furnaces, having hearths of 3 ft. by 5 ft., with the necessary quenching tanks, are used for heat treatment. For gear quenching there are a Klingelnberg and a Gleason quenching press. Tempering is done in a Birlec vertical shaft-type electric furnace.

Practically all the remainder of this bay (about three-quarters of it) is occupied by the tool room, which is equipped with a normal range of machines, and can deal with all the jig, tool, fixture and gauge requirements of the works. An enclosed temperature-controlled portion of the tool room houses three Genevoise jig boring machines.

A large group of machines is devoted to gear cutting. In this section of the works straight spur gears are being cut on Sykes machines in the foreground, while at the rear is a group of Klingelnburg spiral bevel gear hobbers.

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THERMOSTATIC WATER HEATER FOR RAILWAY CARRIAGES

A one-gallon thermostatically controlled water heater suitable for railway rolling stock toilet compartments has been produced by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. It consists of two containers, the inner of copper with welded seams, tested to 6 lb. per sq. in., which is thermally insulated and enclosed in a mild-steel outer casing to which it is bonded electrically. The element assembly consists of two 52 volt, 750 watt sheathed wire elements brazed to a hard brass plate which carries a two-way terminal block. It is fitted to the container by a water-tight joint and can be removed complete. The terminal block is a separate item. A 7 in. thermostat is secured by a spring clip in a tinned copper pocket which is made in the heater during manufacture. The thermostat can be removed without draining the tank. It is adjustable for temperatures of 120, 140 or 160 deg. F. The complete heater measures 13 in. by 10 by $4\frac{1}{2}$ in. overall, and has been shock tested under Admiralty inspection.

TRANSIENT TEMPERATURES IN RACING-CAR BRAKE DRUMS

ANALYSIS OF A HEAT TRANSFER PROBLEM

By Professor F. K. Bannister, PH.D., A.M.I.MECH.E.*

In considering the possible causes of brake fade in racing cars, interest centres on the high temperatures generated at the interface between drum and shoe lining. Among the factors determining these temperatures are the frequency; duration and severity of braking; the road speeds at successive brake applications; the dimensions, form and material of the drums and linings; and the degree of cooling from finning and wheels. A full and precise theoretical analysis would be very complex but interesting conclusions may be derived by considering, as follows, the temperatures occurring in a plain unfinned drum during a single stop on a level track, the retardation being uniform and the initial drum temperature atmospheric.

For simplicity, the system is idealised, the assumptions, discussed later, being as follows. The heat generated at the friction surfaces is considered to flow wholly into the inner surface of the drum, that absorbed by the linings being regarded as negligible. Lateral conduction from the cylindrical to the plane portion of the drum is neglected, as is the cooling loss from the drum exterior. The phenomenon under consideration is thus not the long-term heat dissipation to atmosphere, but the rapid radial spread outwards into the drum material.

The problem is, with small error, regarded as one-dimensional, the cylindrical portion of the drum being developed into a flat rectangular plate with negligible edge losses. Retardation being constant, the heat generation rate diminishes linearly with time.

HEAT-CONDUCTION FORMULAE

The analysis is based on a well-known solution of the Fourier equation for unsteady one-dimensional heat conduction, i.e., of

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}. \quad . \quad . \quad . \quad (1)$$

where T is the temperature, at time t, at a plane distant x from the origin and α the thermal diffusivity of the material, i.e., $\alpha = \frac{K}{C\rho}$, K, ρ and C being, respectively, the coefficient of thermal conductivity, density and specific heat per unit mass.

The solution referred to describes the temperature changes occurring in an infinite slab $(-\infty < x < +\infty)$ of homogeneous material following the operation, for an infinitely short time, of an infinitely strong internal heat source situated on and uniformly distributed over the central plane ($x = 0$) of the slab. It may be shown† that, if such an instantaneous source liberates a total of q heat units per unit area of source plane, then the temperature rise, θ, at a time t' after the instant of heat release is

$$'\theta = \frac{q}{2C\rho\sqrt{\pi}\sqrt{\alpha}} \frac{e^{\frac{-x^2}{4\alpha t'}}}{\sqrt{t'}} \quad . \quad (2)$$

the initial temperature being uniform.

Where heat emission is of finite duration and varying intensity, the solution is obtained from equation (2) by considering a series of instantaneous sources, differing in strength and operating in close succession. Thus, if the rate of continuous heat emission is 2 H heat units per unit time per unit area, where $2H = f(t)$ and t is measured from the commencement of emission, the net temperature rise, θ, at time t will be the summed residual effects of all the instantaneous sources which have operated prior to time t, i.e., at intermediate times τ between 0 and t.

For each such instantaneous source, of duration $d\tau$, the heat generated is $q = 2H\,d\tau = f(\tau)\,d\tau$ and, the interval t' by which the heat release preceded t being $(t - \tau)$, the corresponding contribution $d\theta$ to the net temperature rise at a fixed place and time (x, t) is, from equation (2),

$$d\theta = \frac{f(\tau)\,d\tau}{2C\rho\sqrt{\pi}\sqrt{\alpha}} \frac{e^{\frac{-x^2}{4\alpha(t-\tau)}}}{\sqrt{t-\tau}}.$$

Hence, with x and t constant, integrating from $\tau = 0$ to $\tau = t$ to cover all intervening sources, the net temperature rise, θ, at (x, t) is

$$\theta = \frac{1}{2C\rho\sqrt{\pi}\sqrt{\alpha}} \int_{\tau=0}^{\tau=t} \frac{f(\tau)\, e^{\frac{-x^2}{4\alpha(t-\tau)}}}{\sqrt{t-\tau}}\, d\tau$$

or, substituting

$$\beta = \frac{x}{2\sqrt{\alpha}\sqrt{t-\tau}}, \quad \text{i.e. } \tau = \left\{t - \left(\frac{x^2}{4\alpha\beta^2}\right)\right\},$$

i.e., with x and t constant, $d\tau = \left(\frac{x^2}{2\alpha\beta^2}\right) d\beta$, then

$$\theta = \frac{x}{2K\sqrt{\pi}} \int_{\beta=\frac{x}{2\sqrt{\alpha}\sqrt{t}}}^{\beta=+\infty} \frac{f\left\{t - \left(\frac{x^2}{4\alpha\beta^2}\right)\right\}}{\beta^2} e^{-\beta^2}\, d\beta. \quad . \quad . \quad . \quad (3)$$

This applies only to the positive half of the slab; for $x < 0$ the upper limit becomes $\beta = -\infty$. The modified expression gives the same θ values for negative values of x as does equation (3) for corresponding positive values, the implied θ symmetry about $x = 0$ thus confirming that the heat 2 H emitted by the source divides equally between the two halves of the slab. An important conclusion is that equation (3) is also valid for a semi-infinite slab $(0 < x < +\infty)$ if the source is on the exposed face ($x = 0$) and is of intensity $H = \frac{1}{2} f(t)$.

HEAT INPUT TO SEMI-INFINITE SLAB

If, on the exposed face ($x = 0$) of a semi-infinite slab $(0 < x < +\infty)$, heat is generated at the steadily diminishing rate of $H = N(1 - Mt)$, where N and M are constants and generation starts at $t = 0$, then, in equation (3),

$$f(t) = 2H = 2N(1 - Mt).$$

Hence, the temperature rise, θ, at a depth x and time t is given by

$$\theta = \frac{x}{2K\sqrt{\pi}} \int_{\frac{x}{2\sqrt{\alpha}\sqrt{t}}}^{+\infty} \frac{2N\left\{1 - M\left(t - \left(\frac{x^2}{4\alpha\beta^2}\right)\right)\right\} e^{-\beta^2}}{\beta^2}\, d\beta$$

or, for convenience, writing $\frac{x}{2\sqrt{\alpha}\sqrt{t}} = \phi$,

$$\theta = \frac{2N\sqrt{\alpha}\sqrt{t}\,\phi}{K\sqrt{\pi}} \left\{(1 - Mt)\int_{\phi}^{+\infty} \frac{e^{-\beta^2}}{\beta^2}\, d\beta + Mt\,\phi^2 \int_{\phi}^{+\infty} \frac{e^{-\beta^2}}{\beta^2}\, d\beta\right\}.$$

Hence, integrating by parts and rearranging

$$\frac{\theta K}{2N\sqrt{\alpha}\sqrt{t}} = \frac{e^{-\phi^2}}{\sqrt{\pi}}\left\{1 - \tfrac{2}{3} Mt(1 + \phi^2)\right\} - \phi\left\{1 - Mt\left(1 + \tfrac{2}{3}\phi^2\right)\right\}\left\{\frac{2}{\sqrt{\pi}}\int_{\phi}^{+\infty} e^{-\beta^2}\, d\beta\right\}. \quad . \quad . \quad . \quad (4)$$

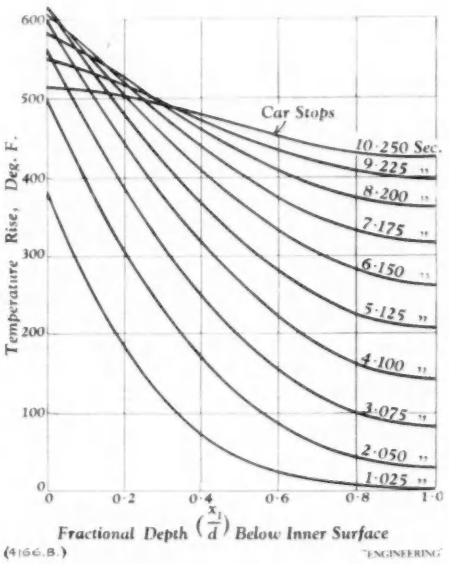

Fig. 2 Temperature variation in drum wall.

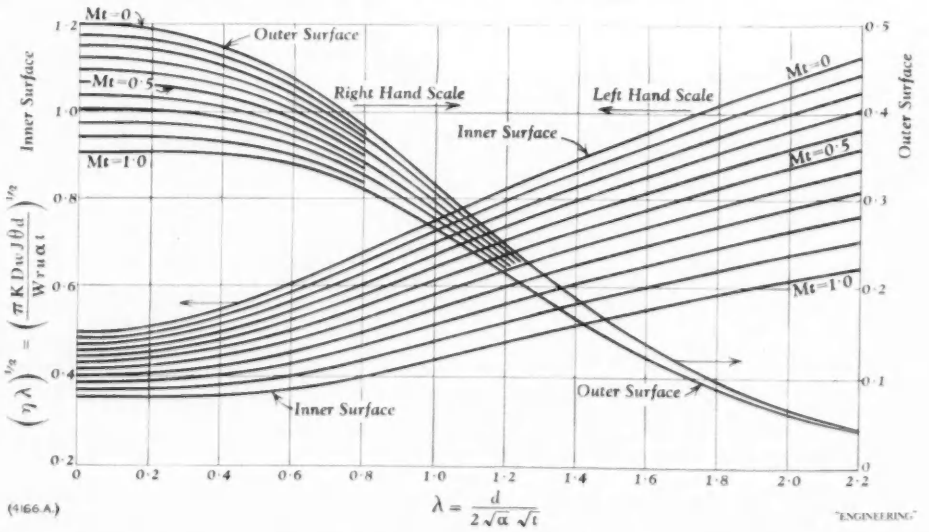

Fig. 1 Chart of parameters relating the temperatures on the inner and outer surfaces of a finite plate with the given heat source.

* Graduate School of Thermodynamics and Related Studies, Mechanical Engineering Department, University of Birmingham.

† Ingersoll and Zobel, *Heat Conduction* McGraw-Hill, 1948.

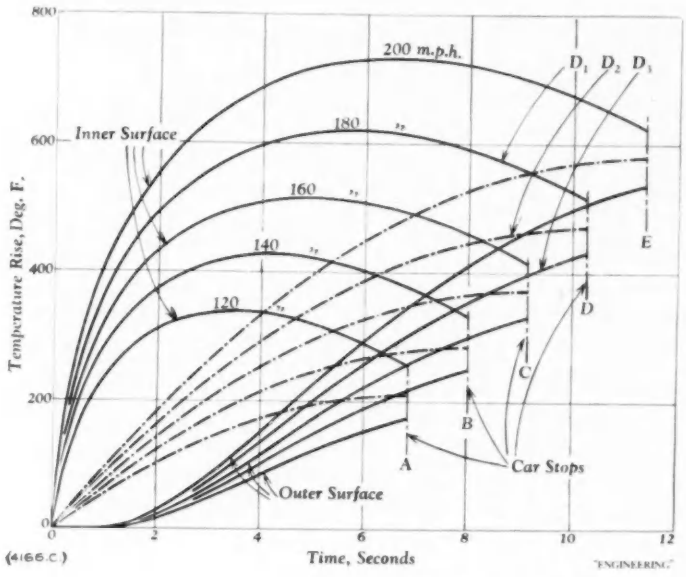

Fig. 3 (left) Effect of initial speed on the temperature rise on the brake drum surfaces of fast car rapidly brought to a standstill.

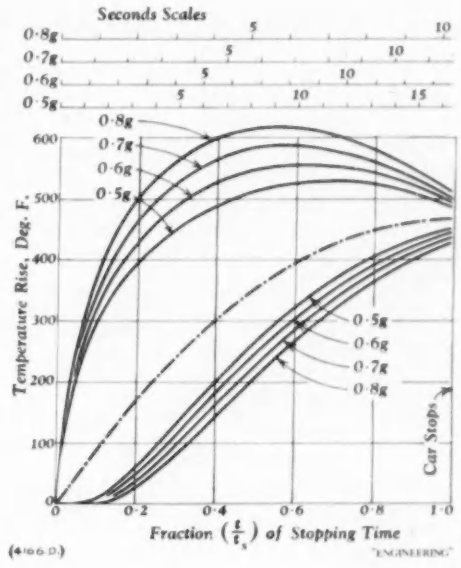

Fig. 4 (right) Effect of retardation rate. Initial speed 180 m.p.h.

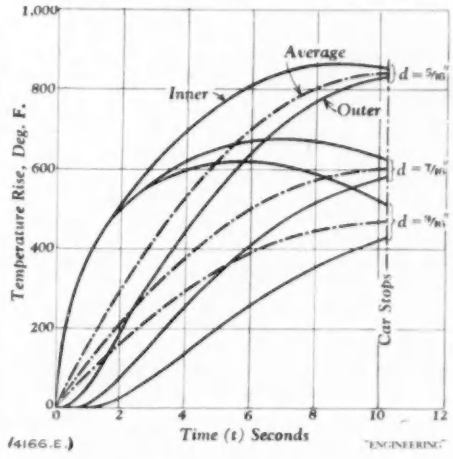

Fig. 5 (below) Effect of drum thickness.

The error function erf $y = \frac{2}{\sqrt{\pi}} \int_0^y e^{-s^2}\, ds$ is well known and tables relating erf y and y are available.* In particular, when $y = +\infty$, erf $y = 1$ and hence, rearranging the limits, equation (4) may be written

$$\eta = \frac{e^{-\phi^2}}{\sqrt{\pi}} \left\{1 - \tfrac{2}{3} \mathrm{M}\, t\, (1 + \phi^2)\right\} - \phi \left\{1 - \mathrm{M}\, t\, (1 + \tfrac{2}{3} \phi^2)\right\} \{1 - \mathrm{erf}\ \phi\} \quad . \quad . \quad . \quad (5)$$

where $\eta = \dfrac{\theta \mathrm{K}}{2 \mathrm{N} \sqrt{\alpha} \sqrt{t}}$.

Thus, for a semi-infinite slab with linearly diminishing heat input $\mathrm{H} = \mathrm{N}(1 - \mathrm{M}t)$ at the exposed face, the value of θ at (x, t) may be determined from equation (5) in conjunction with the tables, provided K, C, ρ, N and M are known.

HEAT INPUT TO PLATE OF FINITE THICKNESS

Where the plate is of finite thickness, d, as in the brake drum development, the heat flow at the outer surface ($x = d$) is zero, a boundary condition not satisfied by equation (5). By application of the method of images, however, the results of equation (5) may still be used, the principle being to place on planes $x = 0$, $\pm 2d$, $\pm 4d$, $\pm 6d$, etc., within an infinite slab ($-\infty < x < +\infty$) a series of similar sources, each of strength $2\mathrm{N}(1 - \mathrm{M}t)$.

With this arrangement, symmetry shows the net flow at $x = d$ due to sources at $x = +2d$, $-4d$, $-6d$, etc., to be neutralised by the opposite flow due to those at $x = 0$, $-2d$, $-4d$, etc., the condition of zero flow at $x = d$ thus being realised. Also, immediately adjoining $x = 0$, the flow due to the symmetrical source system $x = \pm 2d$, $\pm 4d$, $\pm 6d$, etc., being zero, the net flow is that due to the single source $2\mathrm{N}(1 - \mathrm{M}t)$ at $x = 0$.

The boundary conditions thus being similar, the flow and temperature distribution within the range $0 < x < d$ of the multiple-source infinite slab are identical with those in a brake drum in which the inflow is $\mathrm{N}(1 - \mathrm{M}t)$ at $x = 0$ and the outflow zero at $x = d$.

Thus, the temperature rise, θ, at position $x = x_1$ in the brake drum is equal to that at a point in an infinite slab due to a series of sources, of strength $2\mathrm{N}(1 - \mathrm{M}t)$, distant x_1, $2d \pm x_1$, $4d \pm x_1$, etc., from that point. Hence, substituting $\phi = \dfrac{x_1}{2\sqrt{\alpha}\sqrt{t}}, \dfrac{(2d - x_1)}{2\sqrt{\alpha}\sqrt{t}}, \dfrac{(2d + x_1)}{2\sqrt{\alpha}\sqrt{t}}$, etc., successively in equation (5) and summing results, the temperature rise, θ, at a depth x_1 below the input face of the drum, is obtained. Thus

$$\eta = \frac{\theta \mathrm{K}}{2 \mathrm{N} \sqrt{\alpha} \sqrt{t}} = \sum_{n=0}^{n=+\infty} \left[\frac{e^{-\phi_n^2}}{\sqrt{\pi}} \left\{1 - \tfrac{2}{3} \mathrm{M}\, t\, (1 + \phi_n^2)\right\} - \phi_n \left\{1 - \mathrm{M}\, t\, (1 + \tfrac{2}{3} \phi_n^2)\right\} \{1 - \mathrm{erf}\ \phi_n\}\right] \quad . \quad . \quad . \quad (6)$$

where, for each value of the integer n other than zero, the summation is to include two terms, based respectively on

$$\phi_n = \frac{(2nd + x_1)}{2\sqrt{\alpha}\sqrt{t}} \quad \text{and} \quad \phi_n = \frac{(2nd - x_1)}{2\sqrt{\alpha}\sqrt{t}}.$$

For $n = 0$, however, only one term must be used, namely, that for $\phi_0 = \dfrac{x_1}{2\sqrt{\alpha}\sqrt{t}}$.

Cases of major interest in brake calculations are those of $x_1 = 0$ and $x_1 = d$, corresponding respectively to the inner and outer drum surfaces. For these, the various values of ϕ_n reduce to integral multiples of $\dfrac{d}{2\sqrt{\alpha}\sqrt{t}}$ and equation (6) becomes:

For the inner surface, ($x_1 = 0$),

$$\eta = \frac{\theta \mathrm{K}}{2 \mathrm{N} \sqrt{\alpha} \sqrt{t}} = \left\{\frac{1 - \frac{2}{3} \mathrm{M}\, t}{\sqrt{\pi}}\right\} + 2 \sum_{n=1}^{n=+\infty} \left[\frac{e^{-(2n\lambda)^2}}{\sqrt{\pi}} \left\{1 - \tfrac{2}{3} \mathrm{M}\, t\, (1 + (2n\lambda)^2)\right\} - 2n\lambda \left\{1 - \mathrm{M}\, t\, (1 + \tfrac{2}{3} (2n\lambda)^2)\right\} \{1 - \mathrm{erf}\, (2n\lambda)\}\right] \quad . \quad . \quad . \quad (7)$$

where $\lambda = \dfrac{d}{2\sqrt{\alpha}\sqrt{t}}$ and only a single term is required for each value of n. For the outer surface, ($x_1 = d$),

$$\eta = \frac{\theta \mathrm{K}}{2 \mathrm{N} \sqrt{\alpha} \sqrt{t}} = 2 \sum_{n=0}^{n=+\infty} \left[\frac{e^{-(2n+1)^2\lambda^2}}{\sqrt{\pi}} \left\{1 - \tfrac{2}{3} \mathrm{M}t (1 + (2n+1)^2 \lambda^2)\right\} - (2n+1)\lambda \left\{1 - \mathrm{M}\, t\, (1 + \tfrac{2}{3} (2n+1)^2 \lambda^2)\right\} \{1 - \mathrm{erf}\, ((2n+1)\lambda)\}\right] . \quad (8)$$

In practice, good accuracy is obtained using only the first few terms of the summation, the number required increasing when d is small or t large.

Equations (7) and (8) show that, for surface temperatures, the group $\eta = \dfrac{\theta \mathrm{K}}{2 \mathrm{N} \sqrt{\alpha} \sqrt{t}}$ depends only on $\mathrm{M}t$ and λ and a chart based on these equations is given in Fig. 1. This shows contours of $\mathrm{M}t$ on a field of $\sqrt{(\eta\lambda)}$ versus λ, the original variable, η, being replaced, for compactness, by $\sqrt{(\eta\lambda)}$, determined from related values of η and λ derived from equations (7) and (8). Given K, α, N, M and d, it is thus possible, for any chosen time t, to calculate $\mathrm{M}t$ and λ and hence to determine from the chart the corresponding value of $\sqrt{(\eta\lambda)} = \dfrac{\theta \mathrm{K} d}{(4 \mathrm{N} \alpha t)^{\frac{1}{2}}}$ and deduce θ.

APPLICATION OF THEORY

If, on a level track, a car of weight W lb. has a constant retardation ($r g$), where $g = 32{\cdot}2$ ft. per sec. per sec., and r the retardation factor, then after t seconds of braking from an initial speed u, the instantaneous speed is $v = u - r g t$ ft. per sec. Hence, assuming for present purposes an equal sharing of the braking force (W r lb.) between the four wheels, the instantaneous energy dissipation per wheel is $\dfrac{\mathrm{W}\, r\, v}{4}$ ft. lb. per sec., the heat inflow per unit area of friction surface thus being, in B.Th.U. per sq. ft. per sec.,

$$\mathrm{H} = \frac{\mathrm{W}\, r}{4 \pi \mathrm{D} w \mathrm{J}} (u - r g\, t) = \frac{\mathrm{W}\, r\, u}{4 \pi \mathrm{D} w \mathrm{J}} \left(1 - \frac{r g}{u} t\right)$$

where D ft. is the internal drum diameter, w ft. the shoe width and J = 778 ft. lb. per B.Th.U.

Thus, $\mathrm{N} = \dfrac{\mathrm{W}\, r\, u}{4 \pi \mathrm{D} w \mathrm{J}}$, $\mathrm{M} = \dfrac{r g}{u}$ and hence, in equations (6) to (8),

$$\eta = \frac{2 \pi \mathrm{K}\, \mathrm{D} w \mathrm{J}\, \theta}{\mathrm{W}\, r\, u \sqrt{\alpha} \sqrt{t}} \quad . \quad . \quad . \quad (9)$$

$$\lambda = \frac{d}{2\sqrt{\alpha}\sqrt{t}} \quad . \quad . \quad . \quad (10)$$

* *Loc. cit.*

$$M\,t = \frac{r\,g\,t}{u} = \text{fraction of total stopping time} \quad . \quad . \quad . \quad (11)$$

$$\sqrt{(\eta\,\lambda)} = \left(\frac{\pi\,K\,D w\,J\,\theta\,d}{W\,r\,u\,\alpha\,t}\right)^{\frac{1}{2}}$$

$$\text{i.e. } \theta = \frac{W\,r\,u\,\alpha}{\pi\,K\,D w\,J\,d}\,t\,(\sqrt{(\eta\,\lambda)})^2 . \quad (12)$$

Figs. 2 to 5, showing the nature of the transient temperature variations, are based on the following data, using the above relationships in conjunction with Fig. 1.

Weight of car, W = 2,250 lb.; internal drum diameter, D = 14·0 in. = 1·167 ft.; shoe width $w = 2\frac{1}{4}$ in. = 0·1875 ft.; drum thickness $d = \frac{3}{16}$ in. = 0·0469 ft. (unless otherwise stated); drum material, cast iron for which K = 0·0075 B.Th.U. per ft. per deg. F. per sec., ρ = 474 lb. per cub. ft., C = 0·11 B.Th.U. per lb. per deg. F., and, hence, $\alpha = \frac{K}{C\,\rho}$ = 0·000144 sq. ft. per sec.

Fig. 2, derived from equations (6), (9) and (11) shows, for an initial speed of 180 m.p.h. and retardation 0·8 *g*, the temperature distributions within the thickness of the drum at intervals of 1·025 sec., i.e., one-tenth of the total stopping time. The curves indicate that, in a matter of seconds, very considerable temperatures occur at the internal drum surface, and hence at the friction surface of the lining. Also, in the early stages of braking, extremely high temperature gradients exist near the inner drum surface and the associated thermal stresses in that locality must be very high. The transverse hair cracks sometimes found on the inner surfaces of racing-car brake drums may, indeed, be due to failure of the material in compression.

Curves D_1 and D_3 of Fig. 3 show more clearly the variation, with time, of the temperature rise at inner and outer surfaces respectively, the conditions again being *u* = 180 m.p.h. and *r* = 0·8. For comparison, the chain-dotted curve D_2 shows the temperature changes if spatial variations are neglected, i.e., the ordinates represented the rise in average temperature. For this curve the equation is therefore

$$\theta = \frac{\int_0^t H\,dt}{C\,\rho\,d} = \frac{W\,r\,u}{4\,\pi\,D w\,J\,C\,d\rho}\left(t - \frac{r\,g}{2\,u}\,t^2\right) \quad . \quad . \quad . \quad (13)$$

the heat generated prior to time *t* being spread uniformly throughout the cylindrical portion of the drum. The figure shows that, after an initially rapid increase, the temperature rise at the inner surface (curve D_1) attains a maximum of 615 deg. F. at 5·5 sec. giving a maximum temperature of 680 deg. F. if the initial, atmospheric, temperature is 65 deg. F. The subsequent fall indicates that, the road speed having decreased, the heat input rate to the innermost layer has become less than the rate of conduction away from that layer. At the outer surface (curve D_3) the response is initially much slower but as braking proceeds the temperature rises at an increasing rate and when the car stops, at 10·25 sec., is only 90 deg. F. below that of the inner surface. The maximum difference between the two surface temperatures occurs at 2·5 sec. and is about 480 deg. F., the inner then being 330 deg. F. above, and the outer 150 deg. F. below, the average value (curve D_2).

Fig. 3 also shows similar curve-groups, terminating at points A, B, C and E, for initial speeds of 120, 140, 160 and 200 m.p.h., respectively, other conditions being unchanged. Although the general deviations of the surface curves from the average are seen to increase with initial speed, the ultimate convergence shows average and surface temperatues to be virtually equal when the car stops.

Fig. 4 illustrates, for the same car and an initial speed of 180 m.p.h., the effects of different retardation rates, viz., 0·5 *g*, 0·6 *g*, 0·7 *g*, and, from Fig. 3, 0·8 *g*. For ease of comparison the base expresses the time *t* as a fraction $\frac{t}{t_s}$ of the total stopping time t_s, a single average curve thus sufficing for all four cases; individual time scales appear at the top of the figure. The narrowing of the difference between the two surface temperatures with a reduction in retardation rate is explained by the diminished rate of heat generation and the increased time available for heat conduction in the drum material.

The effects of reducing the drum thickness, illustrated in Fig. 5 for an initial speed of 180 m.p.h. and a retardation of 0·8 *g*, are twofold. Other conditions being equal, the thin drum has a smaller heat capacity than the thick and the average temperature rise is therefore higher. It is, in fact, inversely proportional to drum thickness (equation (13)). A decrease in thickness, however, reduces the excess of inner over average temperature, thereby offsetting to some extent the increased general rise.

Inspection of equations (9), (12) and (13) shows all temperatures to vary inversely as the drum diameter D and shoe width *w* and hence changes in either of these may be allowed for in Figs. 2 to 6 by suitable adjustment of temperature scales only. It is of interest that, for drums having cylindrical portions of equal mass, i.e., *d*D*w* constant, a reduction in thickness decreases the maximum temperature; average temperatures are unaffected but, as described above, local deviations from the average are smaller in the thinner drum.

TEMPERATURE EQUALISATION AFTER BRAKE RELEASE

Equations (6) to (12) may readily be adapted, as follows, to the rapid process of temperature equalisation occurring radially within the drum following a cessation of braking. If braking ceases at time t_c, i.e., if the source H = N (1 − M *t*) then becomes inoperative, the subsequent temperature changes may be determined by considering the source H as continuing beyond t_c but being neutralised by a suitable negative source, H′, superimposed on H and commencing at t_c.

It may readily be shown that, for H′ to be equal and opposite to H throughout the period $t_c < t < t_s$,

$$H' = N'\,\{1 - M'\,(t - t_c)\}$$

where $N' = -N\left(1 - \frac{t_c}{t_s}\right)$ and $M' = \frac{M}{\left(1 - \frac{t_c}{t_s}\right)}$

t_s being the total stopping time under continued braking and *t* being measured from the initial brake application.

The temperature effects of the original source, H, are first calculated as already described. For the period $t > t_c$, the negative temperature changes due to H′ are then determined using equations (9) to (12) and either equation (6) or Fig. 1, as appropriate, the quantities N, M and *t* being replaced, for the neutralising source, by values of N′, M′ and $(t - t_c)$. The combined effect of H and H′ is then determined by algebraic addition.

Fig. 6 shows specimen curves, the initial speed being 180 m.p.h. and retardation 0·8 *g*. The full line curves, showing surface temperatures under continued braking, are those of Fig. 3, as is the chain-dotted curve of average temperature. The broken lines, obtained as described above, represent surface temperatures and illustrate the rapid decay of the temperature difference prevailing at various instants of brake release, viz., at 1·28, 2·56, 5·13 and 7·68 sec. Their asymptotic approach to horizontal lines through appropriate points on the average curve confirms, in some measure, the validity of the treatment.

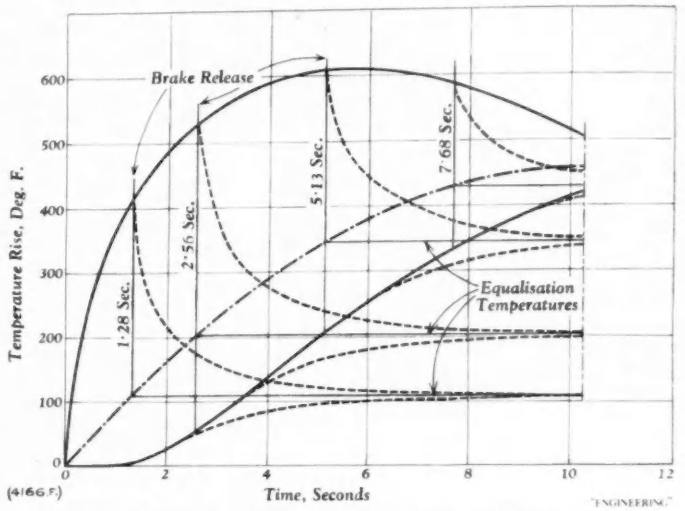

Fig. 6 Temperature equalisation after brake release.

DISCUSSION OF ASSUMPTIONS

Heat Flow to Lining.—A strict analysis of the heat sharing between drum and lining is complicated by different conditions at their non-contiguous surfaces. Conditions approximate to zero flow at the outer drum surface but to constant temperature at the inner surface of the lining, the heat capacity of the metal shoe being large in relation to the heat penetrating the highly insulating lining during a braking period.

Although an exact solution is not here attempted, the sharing is considered to be of a similar order to that if both drum and lining were of infinite thickness, a problem solved below by applying equation (5) to the two semi-infinite slabs in turn. Using suffixes 1 and 2 for drum and lining respectively, the heat division at the friction surfaces is expressed by

$$H_1 = N_1\,(1 - M\,t), \quad H_2 = N_2\,(1 - M\,t) \quad (14)$$

N_1 and N_2 being unknown.

Also, for the common interface, substituting $x_1 = x_2 = 0$, i.e. $\phi_1 = \phi_2 = 0$, in equation (5).

$$\frac{\theta_1\,K_1}{2\,N_1\sqrt{\alpha_1}\sqrt{t}} = \frac{(1 - \frac{3}{5}\,M\,t)}{\sqrt{\pi}} = \frac{\theta_2\,K_2}{2\,N_2\sqrt{\alpha_2}\sqrt{t}} \quad . \quad . \quad . \quad (15)$$

i.e., since the interface temperatures (θ_1 and θ_2 of drum and lining are equal, $\frac{N_1}{N_2} = \frac{K_1\sqrt{\alpha_2}}{K_2\sqrt{\alpha_1}}$.

But, from equations (14), $\frac{N_1}{N_2} = \frac{H_1}{H_2}$ and hence

$$\frac{H_1}{H_2} = \frac{K_1\sqrt{\alpha_2}}{K_2\sqrt{\alpha_1}}.$$

Allowing for different " rubbed areas " (A_1 and A_2) of drum and lining, the net heat absorptions are thus in the ratio

$$\frac{H_1\,A_1}{H_2\,A_2} = \frac{A_1\,K_1\sqrt{\alpha_2}}{A_2\,K_2\sqrt{\alpha_1}} = \frac{A_1}{A_2}\sqrt{\frac{K_1\,C_1\,\rho_1}{K_2\,C_2\,\rho_2}}. \quad (16)$$

Assuming the shoes to subtend a total angle of 140 deg. at the wheel centre, $\frac{A_1}{A_2} = \frac{360}{140}$, and, taking K_1 = 0·0075, K_2 = 0·00010 B.Th.U. per ft. per deg. F. per sec., C_1 = 0·11, C_2 = 0·28 B.Th.U. per lb. per deg. F., and ρ_1 = 474, ρ_2 = 118 lb. per cub. ft., as typical values, the ratio becomes 28. This suggests that the earlier assumption of $H_1 = H$ results in an error of 3 to 4 per cent.

Heat Loss from Drum Exterior.—In estimating cooling losses, only the cylindrical outer surface is considered effective, the heat spread to the plane portion of the drum during a braking period being negligible, as shown later. In the absence of data concerning convection heat losses from a rotating cylinder to a cross-current of

air, use is made of Jürges'* formula for a plane surface, viz.

$$h = \mathrm{B}\, v^{0\cdot78}\,\theta, \quad \mathrm{B} = 0\cdot000145 \quad . \quad (17)$$

where h B.Th.U. per sq. ft. per sec. is the heat loss, v ft. per sec. the relative air speed and θ deg. F. the temperature difference between plane and air stream.

For simplicity, θ is based on equation (13) for average temperature rather than on the more appropriate equation (8) for the outer surface; also the relative air speed is regarded as due solely to bodily motion of the car, i.e., $v = u - r\,g\,t$ as in a previous section. On substituting these relationships in equation (17), integrating, and taking the outer surface area as $\pi\,\mathrm{D}w$, the total heat loss, Q, during the stopping period is given by

$$\mathrm{Q} = \pi\,\mathrm{D}w\int_0^{t_s} h\,dt = \frac{\mathrm{B\,W}\,r\,u^{1\cdot78}}{4\,\mathrm{J\,C}\,\rho\,d}\times \int_0^{\frac{u}{rg}} t\left(1-\frac{r\,g}{2\,u}t\right)\left(1-\frac{r\,g}{u}t\right)^{0\cdot78} dt \text{ B.Th.U.},$$

i.e., on evaluating,

$$\mathrm{Q} = 5\cdot37\times10^{-6}\,\frac{\mathrm{W}}{\mathrm{J}\,r\,\mathrm{C}\,\rho\,d}\,\frac{u^{2\cdot78}}{g^2} \text{ B.Th.U.} \quad (18)$$

Using previously stated values of W, ρ, C and d, the value of Q for 180 m.p.h. initial speed and $0\cdot8\,g$ retardation is thus 11 B.Th.U. This, although over-estimated by using equation (13) instead of equation (8), is only 1·4 per cent. of the heat generated per wheel, the latter being 783 B.Th.U., i.e., one-quarter of the initial kinetic energy of the car. Even for a finned drum using, say, five fins of height $\frac{3}{16}$ in., the cooling area is only increased by a factor 3·5, the cooling loss still being less than 5 per cent.

Lateral Heat Conduction in Drum.—Superimposed on the transient radial flow of earlier sections is the secondary effect of lateral conduction from the cylindrical to the adjoining plane portion of the drum. Strictly, the two effects are inseparable, but useful information concerning the lateral flow is obtained by eliminating the radial process and regarding the heat as generated uniformly within the material of the cylindrical portion. For equivalence with the surface source ($\mathrm{H} = \mathrm{N}(1 - \mathrm{M}\,t)$ of the earlier sections) the generation rate per unit volume is thus, in B.Th.U. per cub. ft. per sec.

$$\frac{\mathrm{H}}{d} = \left(\frac{\mathrm{N}}{d}\right)(1-\mathrm{M}\,t). \quad . \quad (19)$$

In Fig. 7(*a*), showing the development of a radial section through the drum, the cylindrical portion is shown shaded; the plane, i.e., unshaded, portion is for the present considered to extend to infinity. With the above duplicated, as in Fig. 7(*b*), and heat generated in the whole of the shaded section ($-w < \mathrm{X} < +w$), conditions in the right-hand half will, from symmetry, be those of Fig. 7(*a*).

Considering the thin element, $d\mathrm{X}$, of Fig. 7(*b*) as an internal plane source disposed perpendicularly to the figure, the heat generated within it per square foot of its plane is, from equation (19), $\left(\frac{\mathrm{N}}{d}\right)(1-\mathrm{M}\,t)\,d\mathrm{X}$ B.Th.U. per sec. Hence, the contribution, $d\theta$, of the element $d\mathrm{X}$ towards the temperature rise θ, at a fixed plane z is given by equation (5) if N is replaced by $\left(\frac{\mathrm{N}}{2\,d}\right)d\mathrm{X}$ and $\phi = \frac{x}{2\sqrt{\alpha}\sqrt{t}}$ by $\phi = \frac{(z-\mathrm{X})}{2\sqrt{\alpha}\sqrt{t}}$. Thus

$$\frac{\mathrm{K}\,d}{\mathrm{N}\sqrt{\alpha}\sqrt{t}}\,d\theta = \left[\frac{e^{-\phi^2}}{\sqrt{\pi}}\left\{1-\tfrac{2}{3}\mathrm{M}\,t\,(1+\phi^2)\right\} - \phi\left\{1-\mathrm{M}\,t\,(1+\tfrac{2}{3}\phi^2)\right\}\{1-\mathrm{erf}\,\phi\}\right]d\mathrm{X}.$$

The summed effect, θ, at a fixed place and time (z, t) due to all source elements such as $d\mathrm{X}$ is obtainable by integrating from $\mathrm{X} = -w$ to $\mathrm{X} = +w$ with z and t constant. More conveniently writing $d\mathrm{X} = -2\sqrt{\alpha}\sqrt{t}\,d\phi$,

$$\frac{\theta\,\mathrm{K}\,d}{2\,\mathrm{N}\,\alpha\,t} = -\int_{\phi_2}^{\phi_1}\frac{e^{-\phi^2}}{\sqrt{\pi}}\left\{1-\tfrac{2}{3}\mathrm{M}\,t-\tfrac{2}{3}\mathrm{M}\,t\,\phi^2\right\}d\phi + \int_{\phi_2}^{\phi_1}\left\{(1-\mathrm{M}\,t)\,\phi-\tfrac{2}{3}\mathrm{M}\,t\,\phi^3\right\}\{1-\mathrm{erf}\,\phi\}\,d\phi \quad . \quad . \quad . \quad (20)$$

Where

$$\phi_1 = \frac{(z-w)}{2\sqrt{\alpha}\sqrt{t}} \quad \text{and} \quad \phi_2 = \frac{(z+w)}{2\sqrt{\alpha}\sqrt{t}}.$$

Using the relationships

$$\frac{2}{\sqrt{\pi}}\int_0^{\phi} e^{-\phi^2}\,d\phi = \mathrm{erf}\,\phi$$

$$\int_0^{\phi}\phi^2\,e^{-\phi^2}\,d\phi = -\tfrac{1}{2}\phi\,e^{-\phi^2} + \tfrac{1}{4}\sqrt{\pi}\,\mathrm{erf}\,\phi$$

$$\int_0^{\phi}\phi\,\mathrm{erf}\,\phi\,d\phi = \tfrac{1}{2}\left\{\frac{e^{-\phi^2}}{\sqrt{\pi}}\phi + (\phi^2-\tfrac{1}{2})\,\mathrm{erf}\,\phi\right\}$$

$$\int_0^{\phi}\phi^3\,\mathrm{erf}\,\phi\,d\phi = \tfrac{1}{4}\left\{\frac{e^{-\phi^2}}{\sqrt{\pi}}\times(\phi^3+\tfrac{2}{3}\phi) + (\phi^4-\tfrac{3}{4})\,\mathrm{erf}\,\phi\right\}$$

equation (20) may be integrated and rearranged as

$$\frac{\theta\,\mathrm{K}\,d}{\mathrm{N}\,\alpha\,t} = \left\{\begin{array}{l} \left\{\tfrac{1}{2}-\tfrac{1}{4}\mathrm{M}\,t+(1-\mathrm{M}\,t)\,\phi_1^2 - \dfrac{\mathrm{M}\,t\,\phi_1^4}{3}\right\}\{1-\mathrm{erf}\,\phi_1\} \\ -\left\{\tfrac{1}{2}-\tfrac{1}{4}\mathrm{M}\,t+(1-\mathrm{M}\,t)\,\phi_2^2 - \dfrac{\mathrm{M}\,t\,\phi_2^4}{3}\right\}\{1-\mathrm{erf}\,\phi_2\} \\ -\dfrac{1}{\sqrt{\pi}}\left\{\phi_1\,e^{-\phi_1^2}\left(1-\dfrac{5\,\mathrm{M}\,t}{6}-\dfrac{\mathrm{M}\,t\,\phi_1^2}{3}\right)\right. \\ \left. -\phi_2\,e^{-\phi_2^2}\left(1-\dfrac{5\,\mathrm{M}\,t}{6}-\dfrac{\mathrm{M}\,t\,\phi_2^2}{3}\right)\right\} \end{array}\right. \quad . \quad . \quad . \quad (21)$$

ϕ_1 and ϕ_2 being as in equation (20). Evaluation is straightforward for the plane portion of the drum ($z > w$). For the cylindrical portion ($0 < z < w$), however, ϕ_1 becomes negative and, for reasons suggested below equation (3), the bracket $(1 - \mathrm{erf}\,\phi_1)$ must be replaced by $-(1 - \mathrm{erf}\,|\phi_1|)$. Elsewhere in the expression the negative value of ϕ_1 is substituted directly.

Based on equation (21), Fig. 8 shows, for the car considered earlier and for an initial speed of 180 m.p.h. and retardation $0\cdot8g$, the lateral distributions of average temperature at $\frac{t_s}{4}$, $\frac{t_s}{2}$, $\frac{3\,t_s}{4}$ and t_s, i.e. at 2·56, 5·13, 7·68 and 10·25 sec. Particularly in the early stages, the cooling of the cylindrical portion of the drum by lateral conduction is seen to be local. In fact, at the edge ($z = 0$) remote from the plane portion, the curves almost coincide with the horizontal lines, based on equation (13) and showing average temperatures neglecting lateral conduction.

In Fig. 7(*a*) the plane portion of the drum was assumed to extend to infinity and the decrease in sector width with approach to the wheel centre was neglected. That the resultant error is unimportant is shown by Fig. 8, the lateral penetration of heat into this part of the drum during a braking period reaching relatively only shallow depths.

PROBLEM OF REPEATED BRAKING

If, with intermittent braking, the inter-braking periods are more than a few seconds in duration, the equalisation process of Fig. 6 is virtually complete before each new brake application. Thus, if losses were altogether negligible, the initial temperature for each braking operation would be the equalisation temperature from its predecessor and it is to this temperature that the appropriate values of θ would be added. On this basis, however, temperatures would rise without limit as the number of operations increased—an obvious fallacy.

In fact, although only a small fraction of the heat generated in a given braking period is lost during that period, the convection and lateral conduction processes persist indefinitely after brake release and the whole of the generated heat is ultimately lost to atmosphere. Thus, although for the transient changes during any given period the losses may well be neglected, the initial tem-

* Jürges, W., Beihefte zum Gesundheits-Ingenieur, Reihe I. Hefte 19, 19.4.

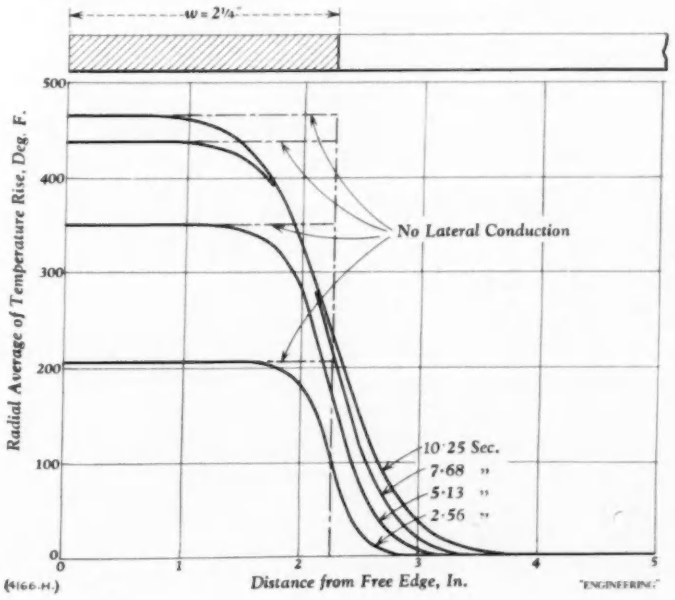

Fig. 8 (left) Effect of lateral conduction, radial variations neglected.

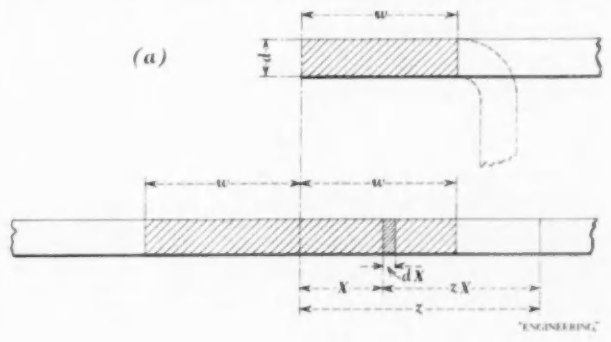

Fig. 7 (right) Lateral conduction through the development of a radial section of a brake drum.

perature for that period depends on the cumulative effects of the long-term losses and its calculation would, in general, be difficult.

If, however, as under track conditions, the braking pattern is cyclic then, neglecting transients, it may be possible to form a fair estimate of the average temperature for the cycle. The transients of previous sections could then, as an approximation, be assumed to occur about this value as mean.

For example, knowing the various initial speeds and retardations for a typical lap, the heat generation per lap, and hence the average rate of dissipation to atmosphere, may be found. Also, remembering that the whole of the drum exterior plus an estimated fraction of the hub and wheel areas participate in long-term cooling, the effective cooling area may be calculated. Thus, regarding the convective process as steady, substitution of the lap speed for v in either Jürges' or a more appropriate formula gives the average lap temperature. The transients during any particular braking-equalisation period may then be determined and their unknown datum adjusted to bring the average lap temperature midway between the initial and equalisation values for the transients. The resulting diagram should give, with fair accuracy, the actual temperatures generated for the braking operation concerned.

CONCLUSIONS

(i) Even during a single stop, transient temperatures of the order of 550-800 deg. F., may occur in the brake drums of a racing car.

(ii) The very severe radial gradients of temperature may result in high thermal stresses and drum distortion.

(iii) Increasing either the drum diameter or shoe width reduces the temperature at the friction surfaces. Decreasing the thickness causes a general increase in drum temperature but reduces the temperature differences between inner and outer surfaces.

(iv) During a given braking period the heat generated remains largely in the cylindrical portion of the drum. Only after an appreciable interval is any considerable proportion conducted laterally from the cylindrical drum for subsequent dissipation from the plane drum face or wheel hub.

(v) Air cooling is a long-term effect which may be neglected in considering transient changes.

(vi) The heat absorbed by the brake linings during a braking period is only a small part of that generated probably 3 to 4 per cent.

STANDARDS ARE A SPRINGBOARD

Printed Circuits, Automation, Electronic Computers

So that existing standards and specifications remain under constant review, standards engineers must keep in close touch with research and development. Standards cannot be static otherwise they specify things that are no longer useful; they may even tend to retard technical advance. It is with this in mind that the latest issue of *Standards Engineering* takes research and progress as its main theme.

Standardisation is a tool and not an end in itself, and specifications should not become a safe retreat for out-of-date ideas and disused methods. If they deteriorate in this way they are rejected by the user. They represent a stopping place, a consolidation of current practice—or a springboard from which the next leap forward can be made. The job of the standards engineer must encompass all phases of research, development, production and control. In order to be successful, standardisation must be backed by top-level management, as must inspection or quality control.

Published standards represent a summary of what has been well done up to that time. They serve as guides or aids to design, so that available talent can be used for putting new ideas into practice. Otherwise engineers may become preoccupied with searching manufacturers' voluminous catalogues for the correct gasket, O-ring, split-pin or hinge. It might be objected that such detail could be safely left to junior draughtsmen, but anyone's time is worth saving. Most of us get enmeshed in detail sometime or other, and detail often draws the dividing line between success and failure in the application of a new idea. The American Army Corps of Engineers found that a substantial saving in the cost of spares was effected by adopting a standard internal-combustion engine for several different duties. In some of the newer industries in this country, such as oil refining, the amount of investment in capital equipment per head of operating personnel is very large indeed. Spares requirements are also large in cost and in numbers, and in an organisation with a number of plants their total value may be tens of thousands of pounds. If it were not for a certain degree of standardisation the stock would be even larger.

The Standards Engineers' Society, which publishes *Standards Engineering*, feel that with rapid progress being made in the fields of printed circuits, automation, electronic computers and nuclear energy it is highly desirable that standardisation be considered in the early stages of research and design. If a company is to realise the full potentialities of computers and data handling equipment, it is evident that records, equipment and methods must be standardised throughout the organisation in a manner suited to the new machines. Another aspect is the possible incompatibility between different manufacturers' devices and interconnection methods. This might necessitate the use of special apparatus for conversion from one system to another, as when it is desirable to fit the photocell unit made by A and the amplifier by B, because each is the best in its field. Without standardisation or the use of converters the alternative is to be tied entirely to the products of one manufacturer.

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GRINDER STORY

Growth of Churchill's

Seldom can the development of a machine tool have been so intimately associated with the growth of a company as the grinder with Churchill's. The publication of *The Story of the Churchill Machine Tool Company, Limited*, is a reminder that the 50 years of the company's existence are largely coincident with the emergence of the grinding machine as a production tool. Grinding is a very old operation, but in 1906, when the Churchill Machine Tool Company was founded, the grinder was looked upon as a necessary evil in most shops. It was simply a means of cutting something which was too hard to cut otherwise, and grinding was usually confined to the finishing and sharpening of cutting tools. Many a fitter, no doubt, then as later, saved himself some hard filing by a little unofficial use of the shop emery wheel intended for tool grinding, but the idea that grinding could become a common production process must have appeared very far-fetched indeed.

It was really the growing automobile industry which gave grinding its first opportunity to develop as a machine tool, and the association of the two industries was to their mutual advantage. Motor cars needed large quantities of components made to precision limits, and it was here that the grinder first came into its own. Once established, the principle of precision grinding has never looked back. The application of hydraulics to the grinding machine, automatic sizing, and the introduction of designs which were then quite unorthodox, such as the centreless grinder, are landmarks in the establishment of the grinding machine as a production tool in its own right.

The Churchill Machine Tool Company started, as was so often the case, by making many different types of machine tool, but soon decided to concentrate on grinders, and they have been associated with many of the important developments in grinding machine design and manufacture. Their history provides yet another example of an early decision, which might have seemed doubtful at the time, being justified by events. Churchill's and grinding are inseparable; they have grown together from nothing.

What the next half-century will bring it is obviously impossible to say, but there are indications of the general trend. Like other machine tools the grinder is already operating in the field of automation, and there seems no reason to doubt that this development will continue at an increasing rate.

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SHIP'S STEERING GEAR

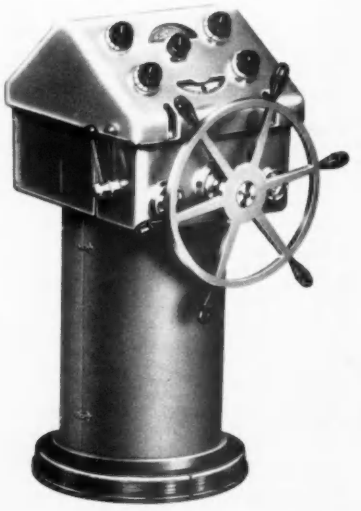
Automatic Gyroscope and Hand Control Combined

In collaboration with the principal ships' steering-gear manufacturers in the United Kingdom, the Sperry Gyroscope Company, Limited, Great West-road, Brentford, Middlesex, have developed a new form of steering control gear which has been given the generic title of Gyro-Hydraulic steering control. Consisting essentially of an integration of the conventional hydraulic telemotor and Sperry two-unit Gyropilot, the new gear will provide, from a single control unit in the wheelhouse, all the features of the two separate systems, namely, hand-hydraulic telemotor, hand-electric telemotor, and automatic steering by gyroscope.

The accompanying illustration of the wheelhouse unit shows that a single hand steering wheel is used on a compact steering stand which actually occupies about the same space as the previous hydraulic telemotor control on its own. All the Gyropilot controls are located together on the sloping panel on the top of the stand.

The first version of Gyro-Hydraulic steering control to go into service will be that combining the Sperry Gyropilot with the Hastie hydraulic telemotor. Similar equipments combining the Donkin and MacTaggart Scott hydraulic telemotors with the Sperry Gyropilot are now in an advanced stage of development.

Orders for nearly 100 sets of the new Gyro-Hydraulic steering control systems have already been placed.



Bridge control unit of the "Gyro-Hydraulic" ship's steering control, which embodies in one unit remote hand control and automatic steering.

VERSATILE TRANSFER PRESS

PROVISION FOR FOURTEEN OPERATIONS

For those articles of comparatively small size which involve press work in their formation, Headland Engineering Developments, Limited, 164-168 Westminster Bridge-road, London, S.E.1, are now marketing the Derota precision transfer press made by the Platarg Manufacturing Company, Limited. It is a multi-tool press, designed for blanking, piercing and forming small parts from strip, with a limiting force of 3 tons for any one operation. It is shown in Fig. 1. Basically, the press is made up of a cross-frame in which provision has been made for eleven vertical plungers and two swinging arms, one of which can give a cross travel if required. For the normal set-up the two outer plungers operate transfer slides for moving the blank under the different punch and forming tools, and the first of the swinging arms is used to operate the feed mechanism.

The strip material is mounted on a reel on the projecting arm, and is fed down under a roller clamp, which is closed on the forward movement by one of the vertical plungers to grip the strip as it is passed into the blanking die. A free-swinging link resting on the strip behind the feed clamp, acts as a safety lever, to stop the press when the supply of strip is used up. When the arm of the lever no longer has strip to rest on, it naturally falls, and, in so doing, connects with a trip lever bearing on the stop button of the motor, so that, on the next stroke of the feeding mechanism, the motor is stopped. The remaining vertical plungers can be used to carry out any desired blanking or forming operation.

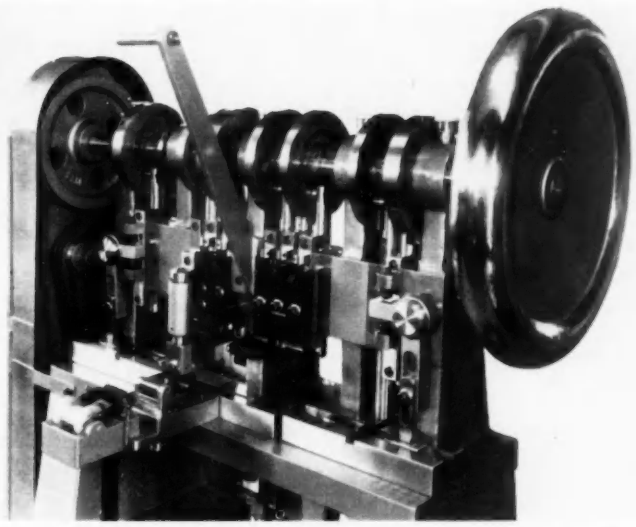


Fig. 1 Versatility is the keynote of the Derota transfer press. In addition to the vertical motions it has two transfer slides and provision for two cross travel movements.

An example of the work which is carried out on this press is the half of the necklace clasp, which is shown in Fig. 2. This is made from aluminium strip. The first operation is a blanking one, and the blank is carried by the punch from the upper part of the die into the lower, where it nests in the transfer slide. At the same time the eyelet and catch hole are pierced, the piercing tool passing through the blanking punch. The transfer slide then comes into operation and moves the blank under the first forming tool, which bends up the sides and cranks the eyelet. A retaining pin on the succeeding plunger holds the work in its new position (which is below the transfer slide), when the forming tool is withdrawn. The left-hand transfer slide then moves back to its initial position to receive another blank. The next movement is that of the right-hand transfer slide, which slides a square mandrel into the work, so that the sides can be closed in to make the box shape.

The closing of the sides is carried out by the vertical plunger which passes below the bed of the machine and acts upon a lever there which, in turn moving upwards, operates a toggle link to close the tool on the sides of the workpiece, thereby forming the complete box. Ejection follows, and this can either be by a scraper which will dislodge the workpiece from the mandrel on the return stroke of the right-hand transfer slide (should the workpiece adhere to the mandrel) or, more generally, by a pin on the left-hand transfer slide as the latter comes forward with the next blank for forming. The standard rate of production of parts of this size, or, indeed, of any part within the capacity of the press, is 6,000 per hour, which is equivalent to a speed of rotation of the camshaft of 100 r.p.m., a speed at which the life of the machine will be preserved. If the machine is desired to work for any length of time at its full capacity, however, it is desirable to fit a second flywheel at the drive end to smooth the operation.

One of the main claims for the machine is its complete versatility. It can have two horizontal transfer motions, a horizontal cross motion, and up to eight vertical downward operations and one vertical upward operation. It is not envisaged that all of these will be required for any one part,

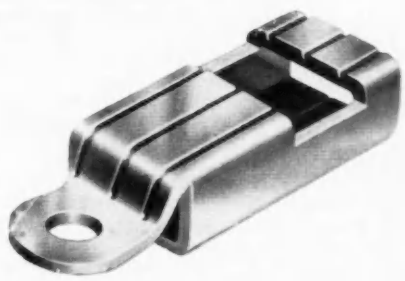


Fig. 2 A typical component which can be made from strip at the rate of 6,000 per hour. The actual dimensions are 0·546 in. long by 0·125 in. deep.

but they are available if necessary. The strokes of the two transfer slides can be varied, as, of course, can their movement times, which are controlled by the cams on the main driving shaft. The strokes are limited by dead-stops on the slides, which therefore give extremely accurate positioning of the blank. An accuracy of 0·0005 in. can be obtained if desired. The blanking and forming tools can also be adjusted in position by means of screw-heads running in grooves on the plunger bodies, and can be locked in position. The standard feed is up to 1¼ in. per stroke and the standard machines will accept strip up to 1½ in. wide of any material providing the 3 ton blanking limit is observed. Wider strips can be accommodated by using special feed clamps. Behind the piercing tool and worked by the same plunger is a scrap cutter which chops off the strip on every stroke and drops it into a tray at the rear. A chute below the blanking die directs the piercings into another tray.

The floor-mounted machine is driven by a 1 h.p. motor through three V-bolts fitted with a tensioner, and the drive is engaged through a dog clutch. The timing of each operation is, of course, governed by the position and formation of the cams on the camshaft. It is recommended that the dies in any complete operation should be mounted on a single block, as this will simplify the process of changing from the manufacture of one component to another. A single block can be set in one operation whereas separate dies would each have to be positioned, requiring the presence of a tool-maker and not only a setter-up. Light drawing operations can be carried out on the press up to a maximum of $\frac{7}{16}$ in. deep but the primary use is for the blanking, piercing and forming of small articles. In addition to the standard model described, a small bench model has recently been introduced, which has one blanking, one piercing and one forming tool, and only one transfer slide. This is arranged with belt pulleys for an external drive.

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ADDING LIGHTNESS

Aircraft Weight-Control Exhibition

Ways in which aircraft designers have achieved useful weight savings through ingenious detail design, development, and the use of some of the newer materials, processes, and equipment, have recently been demonstrated in London by the Society of British Aircraft Constructors in their third display of weight control. Some of the examples on view suggest that the two aspects of the aircraft industry's motto—"Simplicate and add lightness"—are not always compatible; in an intricate component, it may be necessary to resort to considerable complexity in the manufacturing process to achieve the desired lightness. It has, however, been estimated that a saving of 1 lb. in weight is probably worth the expenditure of up to £200-£300, on present-day standards—and as speeds rise the financial value of weight saving increases progressively. The basic problem, therefore, to which the S.B.A.C. drew attention, by a display of charts and graphs near the entrance to the exhibition, was the need to keep constantly under review the equipment and performance requirements of aircraft, and to establish a sound layout in the project stage.

Of most general interest, probably, were the items in the materials and processes sections. The weight-saving possibilities of titanium and its alloys were illustrated, for example, by an undercarriage torque link, comprising a close-to-form titanium forging representing a 42 per cent. saving in weight over a steel forged component; and the use of titanium sheeting for the anti-icing ducts and a hydraulic fluid tank offered a similar weight saving. In the power plant section was seen a compressor rotor disc and blades in titanium, 42 per cent. lighter than the corresponding assembly in stainless steel. The use of magnesium alloy in the form of castings, extrusions and welded tubular structures often replaces aluminium alloy advantageously; and fibreglass is being increasingly used for applications such as ducting, window coamings, and air intakes, with weight savings from 18 to 30 per cent., and for the cladding of control surfaces in place of light alloy sheet. Unexpected weight-savers were G.E.C. heavy alloy mass-balance weights (specific weight 16·8 grams per c.c.) for control surfaces; owing to their compact volume, smaller masses can be concentrated farther from the hinge line.

Other examples of weight-saving included contour-etched skin panels (the process was described in the January 18 issue of ENGINEERING); the Al-Fin molecular bonding process for bonding aluminium and its alloys to steel and iron; and anodically hardened light-alloy bearing rings and valve cylinders.

Book Reviews

PUBLIC APPOINTMENTS

Industry and the State. By P. SARGANT FLORENCE. *Hutchinson and Company (Publishers), Limited*, 178-202 *Great Portland-street, London, W.*1. (10*s.* 6*d.*)

Professor Sargant Florence analyses the various ways in which the State intervenes in the affairs of industry. Broadly speaking there are only three main kinds of intervention but each covers a very wide field. First there is the State as third party keeping the ring for management, labour and consumers. Here it is busy protecting the contestants from each other. Factory and mines Acts, public health Acts, control of monopoly, town planning, company law and patents Acts are all examples of this type of relationship.

Secondly there is the State as the primary party. Here the State takes the initiative and its activities range from such matters as publishing information for industry, providing services such as labour exchanges, trading estates, technical schools right up to running the nationalised industries. The third relationship sees the State as the secondary party exercising control over industry as a whole through the working of national policies. Tariffs, purchase tax, budgetary policy, Bank Rate, rationing, quota schemes and profits tax all come under this heading.

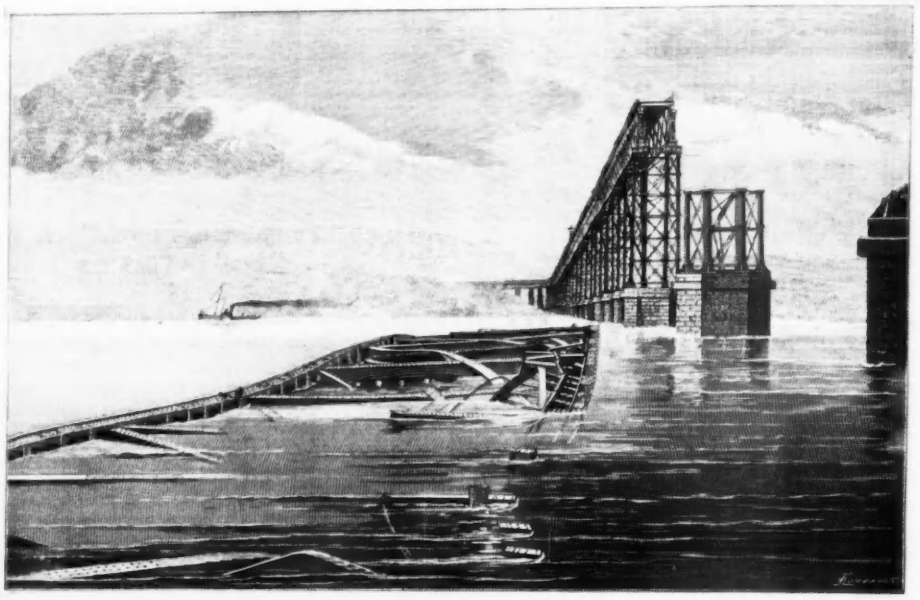
Of these varied activities the State operation of industry is inevitably the one that causes most controversy. The nationalisation Acts of 1946-49 introduced State monopoly into a number of basic industries. The public corporations set up are known under different names in different industries. Each is planned to lead an independent life in an economic and financial sense, while on the organisational and political side a complex set of relationships has been built up between central and regional boards, managers and officers, and on the outer fringes with Parliament and consumers. The differences between the different boards arise from the differing patterns of these relations.

The success or failure of a nationalised industry must depend to a great extent on its central board Whereas a great free enterprise concern will be run by a board of directors who have grown up in the business, nationalised industry is put in the care of a miscellaneous collection of people chosen by the Minister concerned. This system can produce admirable teams of administrators. On the other hand it can produce situations, such as exist to-day on the National Coal Board, where the majority of members have been less than two years on the Board. One of the aims of the creators of the nationalised industry was to make industry more democratic. In fact what has been created is a system in which that new phenomenon the appointed man flourishes.

The other side of the picture is the high level of investment that has taken place in the nationalised industries. From 1951 to 1953 the public corporations including iron and steel, although responsible for only 20 per cent. of the national economy, spent £665 million on plant and machinery. This sum represents over half the amount "spent by persons and companies combined." It does not follow however that this level of investment necessarily makes for efficiency. The usual tests of efficiency—absenteeism, productivity per man, labour turnover—show no improvement taking place.

The iron and steel industry is important as being "the one that got away." Professor Sargant Florence lists certain characteristics which could be taken as grounds for nationalisation. The iron and steel industry requires large and highly equipped plants and "fairly routine management with an expert rather than an 'enterprise' outlook."

Professor Sargant Florence's book brings together and analyses a great deal of information. For those who for the best of reasons are absorbed in the affairs of their own industry it will give an insight into what is going on elsewhere.



The fallen girders of the Tay Bridge. From ENGINEERING *of January* 30, 1880.

THE BRIDGE THAT FAILED

The High Girders. By JOHN PREBBLE. *Martin Secker and Warburg, Limited*, 7 *John-street, London, W.C.*1. (18*s.*)

Of all the failures of railway bridges in Great Britain, none has attracted so much attention and has been so often recalled as the collapse, with the iron portions of their piers, of the 13 central spans of the original bridge across the River Tay. Opened in June, 1878, to connect Fife with Forfar, it failed during a severe gale on the night of December 28, 1879.

The evening mail train giving connection from Edinburgh via the Forth Ferry was hurled into the river, apparently without those in charge receiving the least warning, and all travelling by it, some 78 persons—the exact number seems never to have been definitely established—were drowned. The author gives us, within reasonable compass and in very readable form, the principal facts which led up to and followed the calamity. The seriousness of it led the Board of Trade, acting under authority conferred on it by the Regulation of Railways Act of 1871, which for the first time gave statutory authority to inquiries into railway accidents, to order the setting up of a formal "Court of Inquiry," the last occasion, it is of interest to note, on which that has been considered necessary. The majority and minority reports—the latter by H. C. Rothery, the then Wreck Commissioner—are out of print but the bulky appendix of 633 large pages, containing the minutes of evidence and other valuable information can still be obtained from the Stationery Office, or could be until very recently.

The bridge was designed and constructed under the direction of Thomas Bouch, knighted by Queen Victoria after using the new route for the first time on her return from Scotland in June, 1879. He had been engaged in railway engineering and management, had built many bridges and drawn up plans for one over the Firth of Forth, a small sign of the original works for which still remains. The form adopted by him for the upper part of most of the piers for the Tay Bridge was thought by many to be somewhat frail, even assuming materials and workmanship were of the best, which proved eventually not to have been the case. Bouch had made insufficient allowance for wind pressure and it proved impossible to resist the conclusion that the structure must have failed sooner or later in some manner. The horror of the disaster and the findings of the Court broke Bouch's heart and he died on November 1, 1880.

The events of the fatal night, a Sunday, are vividly recalled, with some attendant strange strokes of fortune and fate, by which, for example, one passenger, sitting in the wrong train to begin with, was led to change into the ill-fated one at the last moment by hearing the call of a porter, while another, who entered his compartment, would have travelled to his death with him but for the arrival in the nick of time of a carriage at an intermediate station, in which he went to a friend's by road. The effects on the minds of those concerned with the trafic working when the train failed to appear at Dundee and when, shortly after, the enormous gap in the bridge was seen, the general public reaction the following day, when it was believed that hundreds had perished, the moralising in and out of pulpits, the finding of the train, the turning of opinion against Bouch, are all recounted in telling fashion.

The author has taken pains to consult numerous and reliable sources of information and, without professing to go into engineering questions in any detailed manner, has presented the essential elements of the disaster, one of the nine instances of train accidents on the railways of the United Kingdom attended with 30 or more fatalities. It is interesting to read that the relief fund established to aid sufferers from the accident was being appealed to as late as just before the last war. The locomotive concerned was recovered, reconditioned and, modified later, ran until 1919, 40 years after plunging into the river.

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FLIGHT FOR THE LAYMAN

High-Speed Flight. By E. OWER and J. L. NAYLER. *Hutchinson's Scientific and Technical Publications*, 178-202 *Great Portland-street, London, W.*1. (30*s.*)

This book is intended for laymen and "experts in other branches of science and engineering." Having set themselves this difficult objective, the authors battle manfully to achieve it. These labours have resulted in a good present for a senior cadet in the Air Training Corps, and more. Much up-to-date information is given, but the standard of the explanation of fundamentals falls well short of that set in Sir Oliver Sutton's *Science of Flight*.

The authors have perhaps been afraid to make the subject too difficult for the reader:

the resulting over-simplifications are sometimes misleading. One example is the very poor discussion of how an aircraft turns (page 44). Another is the impression that radar noise in missile control systems derives solely from aero-elastic effects (page 212).

The chapter headings are: Introduction, The Fundamentals of Flight, The Speed of Sound, Engines for High Speed Aircraft, Aircraft Structures and Materials of Construction, Future Problems of Flying at Very High Speeds—the Human Factor, Research and Experiment in Aerodynamics, Aids to Flight, and Guided Missiles. There is something to interest intelligent laymen in all these chapters but it is a pity that there is almost no bibliography. There are enough errors to make it desirable for the publishers to issue a list of corrigenda.

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NEW BOOKS

Proceedings of the International Pressure Die Casting Conference, London, 1954. *Zinc Development Association, 34 Berkeley-square, London, W.1.* (7*s.* 6*d.*)

In October, 1954, the European Pressure Die Casting Committee, with the help of the Zinc Development Association, held the first international conference ever to be devoted solely to pressure die casting. The conference was held in Westminster, London, and 150 delegates from 13 countries attended and freely exchanged information and ideas on various aspects of the industry. The texts of these discussions and the papers presented, after editing in collaboration with the authors and speakers, have now been published and constitute the present volume of proceedings.

Determination of Moisture in Solids. By P. J. GEARY. *British Scientific Instrument Research Association, "Sira," South Hill, Chislehurst, Kent.* (7*s.* 6*d.*)

Known methods of determining the moisture content of solid materials are surveyed in this publication and lists are given of British instruments and other apparatus used for making measurements of moisture content. Information concerning the possible ways of determining the amounts of moisture in such materials as textiles, crops, foodstuffs, paper, wood, ceramics, plastics, building materials, insulating media, soils, sands, chemicals and solid fuels, have been assembled in one handbook from widely distributed sources in technical and scientific literature.

Electrical Trades Directory, 1957. The Electrical Journal Blue Book. Seventy-fifth edition. *Benn Brothers, Limited, Bouverie House, 154 Fleet-street, London, E.C.4.* (63*s.*)

The classification and arrangement of sections conforms with that already established in previous editions. Lists of companies operating in the electrical and allied industries, together with an indication of their main activities, are included, as are sections on contractors, wholesalers, merchants, patent agents, etc. A further section lists engineers under 27 categories. Information is given on the organisation of the electricity supply system, and details concerning societies, colleges, Government departments, etc., are included

Radio Telemetry. By MYRON H. NICHOLS and LAWRENCE L. RAUCH. Second edition. *John Wiley and Sons, Incorporated, 440 Fourth-avenue, New York 16, N.Y., U.S.A.* (12 dols.); and *Chapman and Hall, 37 Essex-street, London, W.C.2.* (96*s.*)

This volume is intended as a comprehensive survey of the theory and practice of telemetry. It is written mainly from the point of view of radio systems but reference is made to other techniques. The book is arranged in four parts: Part 1, a semi-qualitative presentation of fundamentals; Part 2, a more rigorous development of certain aspects of the theory; Part 3, a discussion of existing radio telemeters; and Part 4, a series of appendices on special topics. The principal additions to the first edition are in Part 3 and include a chapter on data reduction.

Baumaschinen und Baueinrichtungen. Vol. I: Baumaschinen. By O. WALCH. *Springer-Verlag, Reichpietschufer 20, Berlin W.35, Germany.* (37.50 *D.M.*)

The subject of building equipment and organisation is to be covered by several volumes. This, the first, is intended to show the types of machinery available for various operations. As it is explained when, and under which conditions, they can most suitably be used, the information would interest building and civil engineers in addition to those studying constructional engineering, especially as it aims at keeping abreast of the latest developments. Technical mechanical problems are purposely avoided, on the assumption that the reader's knowledge is adequate in this direction. Descriptions, methods of operation and data are given for equipment used for earth and rock removal; foundations; transport and lifting; preparing materials for concrete; and road surfacing. In conjunction with subsequent volumes, the general trend has been to show where such machines can be adopted to practical and economic advantage. There are 291 illustrations and diagrams.

Électricité. By G. GOUDET. Sixth edition. *Masson et Compagnie, 120 Boulevard Saint-Germain, Paris 6e., France.* (4,500 *francs.*)

This comprehensive volume on electricity is now in its sixth edition. It has been brought up-to-date but it still retains the instructional character of former issues which were intended for students and as a reference work for electrical engineers and researchers. In addition to an alphabetical index and detailed indications of the contents, there are bibliographical references sectioned according to the divisions of the book. These enable certain specialised aspects to be studied more closely. Where necessary, the evolution of ideas since the last edition, in 1947, is taken into account by a re-arrangement and revision of the subject matter. Bearing in mind the increasing development in the applications of electricity, the author has limited the text to general laws but care has been taken to express them precisely. The principles of quantum mechanics have been handled fully, bearing in mind that they are indispensable for all atomic problems.

Impianto Idroelettrico Piave-Boite-Maè-Vajont. *Società Adriatica di Elettricità, San Tomà, Palazzo Balbi, Venice, Italy.* (*No price given.*)

Articles by various writers, most of which have appeared in the monthly review " L'Energia Elettrica," are brought together in this volume to provide a description of the Piave-Boite-Maè-Vajont hydro-electric scheme in northern Italy. Geological and hydrological aspects of the area are given as well as constructional details of dams, reservoirs and conduits. Fundamental hydraulic and electro-mechanical principles are explained and so is the machinery and equipment installed at the power stations. The application of the trial load method to dams is accompanied by data and equations relative to the circumstances whilst constructional and functional characteristics of control and safety arrangements are covered by another article. The text is provided with numerous illustrations and diagrams.

* * *

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Nickel Electroplating for Engineers. MOND NICKEL CO. LTD., Thames House, Millbank, London, S.W.1. Description of surface preparation technique in general, and, for zinc base alloys and aluminium and nickel-chromium-iron alloys in particular. Other chapters deal with commonly-used solutions, relevant electroplating procedures; the nature of the plant required; the mechanical properties of deposits; and methods of testing coatings. Illustrated publication of 70 pages written primarily for engineers and designers.

Heat-Treating Furnace. ROYCE ELECTRIC FURNACES LTD., Sir Richard's Bridge, Walton-on-Thames, Surrey. Twin-chamber precision heat-treating furnace for high-speed steels, comprising a 6 kW high-temperature hardening chamber operating at a maximum temperature of 1,350 deg. C., and a 3 kW low-temperature pre-heating and tempering chamber working at a maximum of 1,000 deg. C. Illustrated leaflet.

Electro-Deposition of Metals. FESCOL LTD., North-road, London, N.7. Technical data on the properties of nickel and chromium in various environments and the scope of electro-deposition in the hydraulic-machinery field, the metal industries, paper and printing trades, machine-shop production, and the textile industry. Folder, with two pockets, containing a technical booklet and five leaflets.

Furnaces for Metals. BIRLEC LTD., Tyburn-road, Erdington, Birmingham, 24. Conveyor furnaces of the cast-link, chain and belt, roller, shaker-hearth, walking-beam, rotary-hearth, rotary-drum, and draw-through types, and Birlec-Detroit rocking-arc electric melting furnaces. Brief descriptions of typical installations. New editions of publications Nos. 76 and 65.

Thermostatic Control Systems. STONEBRIDGE ELECTRICAL CO. LTD., 6 Queen Anne's Gate, London, S.W.1. Weather sensitive controllers, for central heating systems, in which magnetic amplifiers are used to increase sensitivity. An external thermostat ensures that the room temperature is properly adjusted with regard to weather conditions. Illustrated leaflets.

Honing Machines. A. A. JONES AND SHIPMAN LTD., Narborough-road South, Leicester. A range of three honing machines built under licence from the Micromatic Honing Corporation, Detroit, U.S.A. The machines are designed for a diameter range of ¼ in. to 1 in., 1 in. to 6 in., and 1½ in. to 8 in. respectively. Illustrated brochure.

Spectrochemical Analysis. HILGER & WATTS LTD., 98 St. Pancras Way, Camden-road, London, N.W.1. Five illustrated brochures on spectrochemical analysis: 1. General principles and bibliography; 2. Sources; 3. Photographic spectrographs; 4. Interpretation equipment; 5. Direct-reading spectrographs.

Skip Hoists and Elevators. MARCO CONVEYOR & ENGINEERING CO. LTD., Rowin Works, Leytonstone, London, E.11. Skip hoist and elevator systems for handling coal, sand, grain, ash, etc. Descriptions of elevators up to 24 in. wide, and of skips for hoppers of up to 25 tons capacity. Illustrated brochure.

Automatic Power Plant. AUSTINLITE LIMITED, Crawley, Sussex. Details of plant for operation as standby to normal mains supply and for use as a self-contained generating station. Analyses of typical problems, and details of individual components used in automatic systems. Illustrated brochure.

Strain-Gauge Bridge. CROYDON PRECISION INSTRUMENT CO. Hampton-road, West Croydon, Surrey. Direct reading strain-gauge bridge for laboratory use with electrical resistance strain gauges of any resistance. Overall range 0·001 per cent. to 0·5 per cent. strain. Illustrated leaflet.

Conducting Lubricating Fluid. ELECTROLUBE LTD., Oxford-avenue, Slough Bucks. Electrolube has water repellant properties and is claimed to have the lowest electrical resistance of any known non-aqueous lubricant. Recommended for switchgear contacts, valve pins, commutators. Leaflet.

Electrical Summation Metering. FERRANTI LTD., Hollinwood, Lancashire. Various types of meters that sum the power in one circuit or several circuits. Maximum demand meters and reactive power meters for various circumstances. Illustrated brochure.

Projectors. HILGER & WATTS LTD., 98 St. Pancras-way, Camden-road, London, N.W.1. Variety of projectors with self-contained translucent screen for close inspection of articles. Magnifications, accurate to 1 part in a 1,000, may be obtained in several values. Illustrated leaflets.

Angle Checker. HILGER & WATTS LTD., 98 St. Pancras-way, Camden-road, London, N.W.1. Simplified auto-collimator for rapidly measuring angles of plane surfaces. A micrometer eyepiece increases accuracy of reading to 1 second. Illustrated leaflet.

Fractional Horse-power Motors. LANCASHIRE DYNAMO & CRYPTO LTD., St. Stephen's House, Victoria Embankment, Westminster, London, S.W.1. Small electric motors for various applications and supplies. Illustrated leaflet.

Steam Systems. SPIRAX-SARCO LTD., Charlton House, Cheltenham. Technical literature on sections of steam systems, including air venting; condensing; calorifiers; textile drying machines; and oil burning installations. Various leaflets.

Oil. THE BRITISH PETROLEUM CO., LTD., Britannia House, Finsbury-circus, London, E.C.2. " The Search for Oil " describes the methods used in the location of supplies of crude oil throughout the world. Illustrated brochure.

Industrial Actuator. ENGLISH ELECTRIC CO., LTD., Queens House, Kingsway, London, W.C.2. Screw jack driven by an induction motor. Capable of precise control of boiler flue dampers from a central control position. Illustrated brochure.

High-Pressure Pumps. G. AND J. WEIR, LTD., Cathcart, Glasgow, 4. Three-throw reciprocating high-pressure pumps for hot and cold liquids. Illustrated leaflet No. 164.

Marketing

DRIVE FOR DOLLARS

To be short of dollars is to lack a vital ingredient in any good recipe for world trade. To this country it is a constant threat. The closure of Suez showed just how much we still depend on loans as soon as the pattern of imports from Sterling sources is disturbed. Yet there is a widespread belief in industry that nothing can be done about it and that it is a waste of energy and money to try to change it.

This has been disproved by the efforts of many firms, but despite the work of the Board of Trade, the Federation of British Industries and the Dollar Exports Council, too little is known about them. These notes give prominence to a few typical cases.

★ ★ ★

British Instruments Gain Ground in U.S.

Telecommunication test equipment, including signal generators, bridges and deviation meters, made by Marconi Instruments, Limited, have found a ready sale in the United States market. According to the company this is due in part to the fact that in specification and price the products compare more than favourably with their many American competitors and in part to there being no American equivalent of some of the instruments. Thus the company are able to market at competitive prices—" despite a formidable tariff barrier "—products which are technically in the forefront. American manufacturers were warned by Mr. F. S. Blackall, Jnr., recently (Weekly Survey, February 8, page 166) that their tariffs could be quite ineffective against determined exporters. The success of Marconi and other precision instrument and electronic tube manufacturers in the English Electric group strongly supports his theory.

Marconi Instruments are exhibiting at the I.R.E. National Show which is being held in New York from March 18 to 21. In addition to their own equipment they will be showing apparatus by the English Electric Valve Company, Canadian Marconi Company, Stratton and Company, Wayne Kerr Laboratories and Cinema-Television Limited. Canadian Marconi will feature their range of cadmium sulphide photo-conductive cells, 5,000 of which are used in the Hudson Highway lighting system in New York city to activate automatic control devices for street lamps. English Electric Valve Company will be showing their Travelling Wave Tubes, which have applications in the fields of radar and micro-wave radio link equipment.

Collectively, the instruments will cover a wide range of requirements in the communications and industrial fields. To reach this stage only six years after opening a New York office is no mean achievement.

★ ★ ★

Hints to Exporters

The manager of a London buying office of an American company, writing in the *Board of Trade Journal*, has analysed the influences working against British exports to the United States. Much of what he has to say relates to consumer goods, but his " tips " go for most types of products:

" We should perhaps concentrate more of our effort on pushing those things which will sell in the United States, and waste less effort on those which, in the very nature of things, will not. I am constantly surprised at being asked to give letters of introduction to salesmen or principals contemplating a selling trip to the United States, and who are taking merchandise which, for one reason or another, cannot hope to sell there. Moreover, by contacting five or six of the London buying offices representing American stores, and seeking their opinion, the traveller could have saved himself time and money."

It is not always as simple to discover whether or not an instrument or a machine will sell in America. But to try to sell without finding out is what caused so many engineering firms to fail after the war. A great deal can be found out in London before setting out.

★ ★ ★

Pumping up the Dollars

What can be done by an energetic young man with a good backing from his company is told in an announcement by Sumo Pumps, Limited, a subsidiary of Stone-Chance, Limited. In 1950 the company sent a 25-year-old technical salesman to sell their electric submersible pumps in the United States. He formed a company, Sumo Pumps Inc., at Stamford, Connecticut. In 1956 the company sold 5,000 pumps worth over a million dollars. The sales account for 12 per cent. of the total American market, despite fierce competition from 32 manufacturers and from imported pumps.

Sumo's success is partly due to their stepping in at a time when the principle of the submersible pump was not generally accepted in the United States. There were only two manufacturers and competition was not the critical problem, which was much more that " of converting well drillers and plumbers to the submersible system." Twenty years of experience in making the pump ensured a high standard of quality, but modifications to the design were necessary to meet requirements of performance and size.

Dealers were appointed throughout the country to hold bulk stocks, to promote sales and to undertake after-sales service. Spare parts are stocked (and were from the outset of the venture) to ensure a 24-hour service anywhere. Recently a film on submersible pumping, featuring the Sumo pump and the film star Conrad Nagel, appeared on American television and will shortly be shown on 125 networks—at no cost to the firm.

★ ★ ★

Scientific Approach

To have a British management consultant invited to lecture American managers is no mean tribute, particularly when the invitations come from organisations such as the American Management Association, the General Electric Company, Monsanto Chemical Company and various others including three universities. But this is no new experience for Lt. Col. L. Urwick, who headed in 1951 the Anglo-American Productivity Team on " Education for Management in the United States." His output is indeed prolific: in the past year it included 66 speeches, two books and a dozen articles, not to speak of regular committee work at the British Institute of Management.

Col. Urwick is exporting the " scientific approach to management problems in industry," with special emphasis on the education of future managers. Taking coals to Newcastle, perhaps, but a valuable fillip to British prestige overseas.

★ ★ ★

Below the Belt

A judge recently found in favour of a British firm who alleged unfair sales practices by an American competitor. Cellactite and British Uralite, Limited, manufacturers of building materials, were awarded damages and costs on the grounds of " the disreputable and deplorable sales policy of the defendants." The latter were H. H. Robertson and Company Inc., who are one of the largest makers of roofing materials in the United States.

Cellactite and British Uralite were sent a document issued by H. H. Robertson to their sales staff in which they alleged that the British material Cellactite had poor non-combustible qualities. This was disproved by research carried out by the Joint Fire Research Organization and the British company duly won the day.

★ ★ ★

Many Costly Impediments

A printed postcard received recently by a British consulting engineer in reply to an inquiry about injection mouldings suggests that exports are no cake-walk even for an American company. The American company wrote:

" The expenses of handling foreign accounts, the difficulties of exchange customs and all the other many costly impediments placed in the way of export business do not justify our attempting to satisfy your request for further information about our products. We regret we cannot be of service to you."

This will strike a familiar note in many British companies, for it has only too frequently been their own bitter experience. Yet many American companies succeed in export markets; where the impediments are too great they start up subsidiaries or licence their products for manufacture locally. British manufacturers can do the same—many of them have done so in North America.

★ ★ ★

Tunnel to Europe

A plea for a Channel tunnel was made by Mr. Reay Geddes, a director of the Dunlop Rubber Company, at the annual dinner of the Institute of British Carriage and Automobile Manufacturers in Birmingham recently. Mr. Geddes considered it " unthinkable " that Britain should enter into a European free market scheme unless British industry was in a position to compete on equal terms. This it could not do unless better and new transport facilities were provided. In his view the need to start work on a tunnel was urgent, for without one we would be at a disadvantage in respect of freight costs.

This is a question which can surely be resolved by a little applied study. It should not be impossible to estimate transport costs by road or rail via a tunnel and to compare them with existing composite rates. Likewise it is not too early to start building up estimates of the increase in traffic likely to result from a gradual elimination of quotas and tariffs between Britain and Western Europe. The construction of a tunnel would go a long way towards creating a climate of opinion in favour of British participation in European free trade.

★ ★ ★

Pye Strike East

The single-minded intensity with which Pye Limited have gone out for exports since the war is illustrated by their latest move to secure business in Eastern Europe. A concentrated drive was launched at the Leipzig Fair which opened this week. Nearly a quarter of a million pounds worth of the most advanced television transmission equipment is being shown and will be offered to the Fair authorities for use when the East German Television Service is off the air.

There are demonstrations of under-water, industrial and studio television cameras as well as a complete outside broadcast vehicle. In addition there are on show telecommunications and scientific instruments, electronic components such as transistors and quartz crystals, and domestic radio, television and sound reproducing equipment. According to the company this drive will be " the largest ever undertaken by Pye in an overseas market."

This is an important reminder, by one of the largest and most enterprising companies in this industry, that rich markets lie east of the Oder. In all these countries and in Russia also the people's thirst for national well-being is acknowledged, and the propaganda value of television recognised, by their governments.

ATOMIC REVIEW

Synthesis of Sciences

FEW studies embrace so many disciplines as nuclear engineering. Thus at present any nuclear project from a reactor to a glove box requires the co-operation of some half a dozen different specialists—physicists, civil, mechanical and electrical engineers, metallurgists and chemists. But the committee approach to an engineering problem is unlikely to be the most successful, and the creation of a chair of nuclear power at Imperial College is welcome recognition of the need for engineers concerned primarily with nuclear problems. Students will presumably cover such aspects of physics, chemistry and engineering as are relevant to their own speciality—in the same way electrical engineers require some knowledge of mechanical and even civil engineering. Engineers trained in the new department at Imperial College will thus be equipped to treat the design of nuclear plant as a coherent problem, rather than as an agglomeration of conflicting elements. Reference to the courses planned is made in a Weekly Survey note on page 294.

One sector of nuclear technology—and one which is sometimes overlooked—is chemical engineering. Though it plays a comparatively small part in reactor design, it is essential to reactor operation, for it is the means by which nuclear fuels are produced and reprocessed after irradiation. Some of the techniques used for this purpose are discussed below.

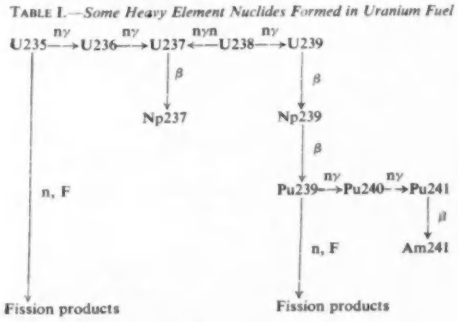
Fuel Chemistry

Fundamental to any nuclear power programme is the provision of facilities for the chemical processing of nuclear fuels. Various techniques devised for this purpose were discussed in a paper recently presented at a meeting of the Institution of Chemical Engineers, in conjunction with the British Nuclear Energy Conference, by Mr. C. M. Nicholls, Chemical Engineering Division, A.E.R.E., Harwell, and Dr. R. Spence, chief chemist and head of Chemistry Division, Harwell. Excerpts from the paper are summarised below.

Fission and Capture Products

The nuclear fission chain reaction on which all present-day nuclear reactors are based consists of a series of transmutations of the elements initially present into a large number of other elements. A chemically pure material, such as uranium, for example, becomes transformed in the reactor into a mixture of fission products and heavy element isotopes dispersed in the original uranium, the concentration depending on the degree of fission which has taken place and on the isotopic composition of the initial uranium. Table I indicates the transformations that occur.

TABLE I.—*Some Heavy Element Nuclides Formed in Uranium Fuel*



Power Reactor Fuel Processing

When the primary function of a nuclear reactor is the production of electrical power rather than of fissile material for weapons, the requirements for chemical treatment are quite different. Plutonium production reactors use natural uranium; they operate at comparatively low temperatures, and, in order to obtain the maximum yield of plutonium 239, the time during which the fuel is irradiated in the reactor is comparatively short. Power reactors, on the other hand, range from natural uranium systems to systems using pure fissile material; operating temperatures range from 300 deg. C. upwards; and long irradiation times with high burn-up of fissile material are favoured in order to improve their economy. The fuel is withdrawn for chemical processing primarily to maintain its performance at some set level which may be determined by nuclear physical, metallurgical, or chemical factors. In natural or slightly enriched uranium power reactors, for example, it is usually the metallurgical life of the fuel element which governs the irradiation period but removal of fission-product poisons and quantitiative recovery of plutonium are also essential requirements. Similar considerations apply to reactors using enriched fuel, with varying degrees of importance. In no case is it necessary to achieve the extremely high decontamination from fission products which is attained in military production plants. A decontamination factor of 10^2 would be more than adequate for power reactors as compared with about 10^6 for existing plants. The residue of 1 per cent. of the fission product activity would mean, however, that both the uranium and the plutonium would still be highly gamma-radioactive so that all operations including the re-fabrication of the fuel element and its insertion in the reactor would require shielding.

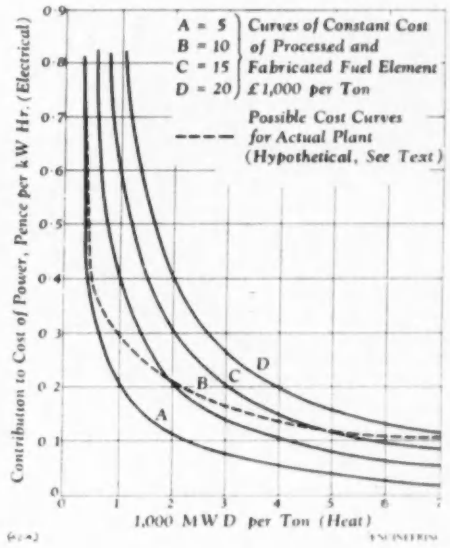


Fig. 2 The cost of fuel processing.

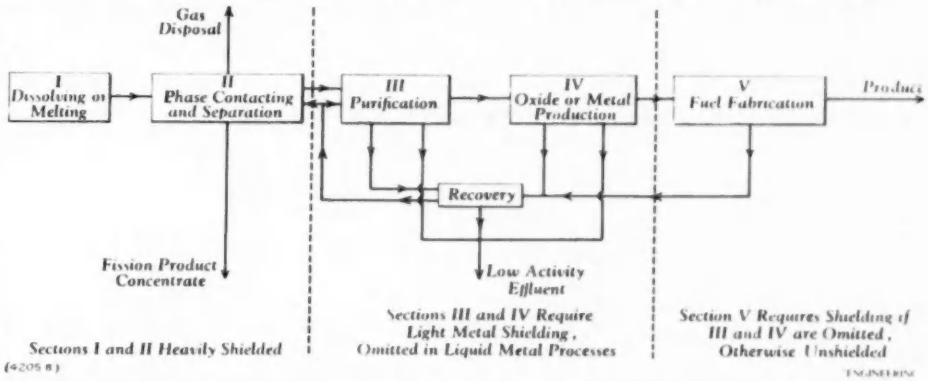

Gas Disposal
I Dissolving or Melting
II Phase Contacting and Separation
III Purification
IV Oxide or Metal Production
V Fuel Fabrication
Product
Recovery
Fission Product Concentrate
Low Activity Effluent
Sections I and II Heavily Shielded
Sections III and IV Require Light Metal Shielding, Omitted in Liquid Metal Processes
Section V Requires Shielding if III and IV are Omitted, Otherwise Unshielded

Fig. 1 In the chemical processing of nuclear fuels, there are a number of distinct stages, in some of which shielding is required.

Process Characteristics

When the problem of chemical treatment is considered in more detail, several general features can be distinguished (see Fig. 1). First of all, the fuel must be removed from its container. Decanning is usually a simple remotely controlled mechanical operation for natural uranium reactors. At the other extreme, some highly enriched fuel elements generate so much heat when they are removed from the reactor that the presence of a heat-transfer agent such as a flowing gas or liquid metal is necessary until the fuel has been dissolved or melted, and this may complicate the decanning operation. The next stage involves the dissolving or melting of the fuel in order to release any trapped gaseous fission products and to bring about a separation from the others. If an aqueous process is to be used, the fuel is usually dissolved in nitric acid. Alternatively, the fuel can be treated with a reagent such as bromine trifluoride so as to convert the uranium into the volatile hexafluoride. It is also possible to effect decontamination and plutonium separation by high-temperature processes in which the fuel is melted.

The design of the fuel element and the chemical composition of the fuel may profoundly affect the removal and dissolving processes. An elaborate shape may provide a difficult decanning problem, and a highly alloyed fuel may be difficult to dissolve and may seriously complicate the problems of fission-product disposal. In addition, the evolution of radioactive gaseous fission products and the presence of non-volatile isotopes present operational problems.

Fuel Standardisation and Remote Control

Standardisation of fuels and simplicity of manipulation during manufacture are probably necessary requirements before active fabrication will be technically and economically feasible. Higher capital investment will be required for remotely controlled operations and the financial savings arising from the adoption of such methods will come from the saving of labour associated with a large throughput of standard articles. At present, fuel elements are far from standard and the current trend is towards more complicated designs to achieve better heat transfer and longer life under irradiation. This trend can be expected to continue until irradiation times of 5 to 10,000 MW days per tonne of fuel are realised; the cost of processing and fabrication would then represent a much smaller fraction of the total cost of power sent out (see Fig. 2).

Separation

Once the fuel has been brought into solution or into liquid form, and the gaseous fission products disposed of, it is the aim in practically all processes to achieve the maximum possible separation of fission products in the next stage. This usually involves phase contacting and phase separation processes such as the formation and separation of co-precipitates, contacting an aqueous phase with an organic solvent or solid adsorbent and their separation, or the formation and separation of slag from a molten metal. It is highly desirable that the fission products which are separated should not be too dilute and should also be in a form suitable for easy separation of long lived constituents or

for economical storage. Furthermore, the greater the degree of decontamination achieved in this stage, the less the shielding required in subsequent stages so that the character, and in many cases the cost, of the remainder of the plant is greatly dependent on the efficiency achieved here. Naturally the greatest separation efficiencies are given by multi-stage counter-current processes such as solvent extraction and this factor has often been dominant in deciding the choice of process.

Considerable information has been published on methods of liquid-liquid extraction (contacting and phase separation) and, as shown by Table II, a wide range of equipment is available from which the plant designer can choose for his particular application.

TABLE II *A Selection of Liquid-Liquid Contacting Equipment*

Type	Characteristics
Vertical:	
Non-mechanical ..	Packed and perforated plate columns
Mechanical	Pulsed columns, rotary columns
Multiple columns in parallel	Small-diameter columns
Multiple columns in series	"Concatenated" pulse columns
Horizontal:	
Mixer settlers	Mechanical mixing—no pumping
	Mechanical mixing and separate pumping
	Mechanical mixers which pump
	Air lift mixing and pumping
	Pulsed ejector mixing and pumping

While adaptations of these multi-stage contacting methods could, in principle, be used with liquid metals or liquid metals and fused salts, limitations on constructional materials at high temperatures will permit only the simplest methods in practice. In the case of molten uranium at temperatures of about 1,200 deg. C., for example, materials of construction are probably limited to graphite, ceramics, or tantalum, and liquid-liquid contacting can only be contemplated in the simplest single-stage operations.

Recent Process Developments

Perhaps the most important recent development has been the introduction of the solvent tributyl phosphate by American workers. It is used as a solution in kerosine or similar solvent. High decontamination factors are obtained in presence of nitric acid and a salt-free fission product waste can be produced, easily concentrated by evaporation. This solvent has a high stability to radiation as well as to nitric acid but some of the products of the radiation decomposition have an adverse effect on extraction efficiency. These effects only become significant, however, at high radiation intensities, as might be encountered after short decay periods.

Methods based on the use of ion-exchangers, or chelating agents such as thiophenoyl trifluoroacetone (TTA) have been examined in many laboratories but they do not appear to offer any advantages over solvent extraction. Halogenation methods have naturally attracted considerable attention, especially since fluorinating agents such as bromine trifluoride and chlorine trifluoride have become available commercially. Fluorination processes already play an important part in atomic energy operations, in the production of uranium hexafluoride for example, and there are strong arguments in favour of a fluoride separation process which can be closely integrated with an overall fluoride cycle involving diffusion plant, isotopic blending and metal production. The dissolving and phase-contacting stages of a fluorination process based on the use of chlorine trifluoride are shown diagrammatically in Fig. 3. Uranium hexafluoride is produced with a decontamination factor high enough to permit it to be converted to metal in an unshielded plant. Any plutonium present in the fuel is left behind with the non-volatile fission products, from which it is, in principle, separable by distillation as PuF_6 at a higher temperature.

A technically feasible method of accomplishing this has not yet been developed so that the applicability of the fluoride process is rather restricted. Its many attractive features appear to be counterbalanced, for the present, by the cost and hazardous nature of the reagents and by such problems as corrosion and criticality.

Melting and Casting

The recycling of any solid metallic fuel element usually involves a final melting of the reconstituted metal before casting, although this stage might be dispensed with if powder metallurgical techniques were used. It has been shown that useful decontamination from fission products occurs during the melting of irradiated uranium metal, owing to the formation of a slag by the impurities present, and this suggests the possibility of a simple process in which the fuel is withdrawn from the reactor, decanned, melted, recast, and refabricated in its can (Fig. 4).

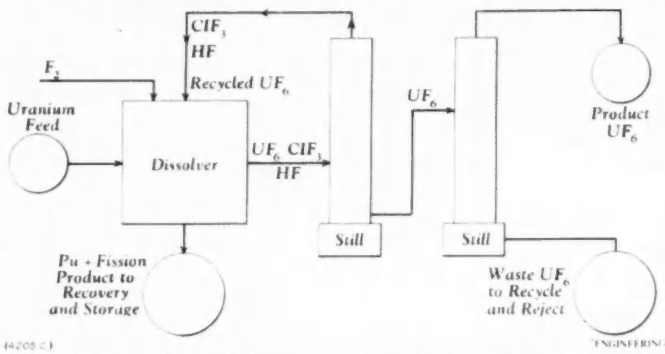


Fig. 3 Chlorine trifluoride process for separating uranium from plutonium and fission products.

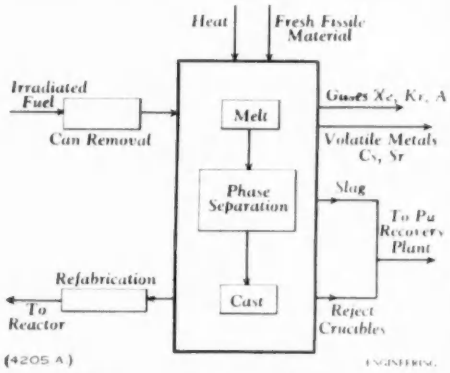


Fig. 4 High-temperature slagging process. Since the impurities present in irradiated uranium tend to form a slag on melting, a slagging process may be used for fission-product decontamination.

Other more elaborate treatments of the molten fuel have been suggested in which fused salts or other molten metals are used. Such processes may be particularly valuable when only a short decay period can be allowed. It will be necessary to do this for fast reactor fuels if high burn-up cannot be achieved since a long decay period would substantially increase the overall inventory of fissile material. Remote re-fabrication of the fuel would, of course, be essential and the economic attractiveness of the high-temperature process would be greatly influenced by the cost of this requirement.

Processing Cost

Chemical processing is profoundly affected by the nature of the reactor fuel cycle. For example, "once through" systems are conceivable in which burn-up in the reactor is so high that the fuel can be discarded without processing, whilst at the other extreme, fuel elements which permit only low burn-up in an otherwise efficient reactor might justify several processing cycles. Thus, the nature of the fuel cycle directly influences the throughput. Since, however, the processing cost per kilogram of fissile material is an inverse function of the throughput, the reduction in the overall cost accompanying an increase in the irradiation time will not be so great as might at first sight be expected. This is illustrated in Fig. 2, which also brings out the interesting result that processing costs per unit of electrical power generated tend to decrease only very slowly with increase of irradiation time beyond about 4,000 MW days per tonne. The cost figures quoted in Fig. 2 are, of course, purely hypothetical, since insufficient data have so far been published concerning actual industrial plants on which to base a cost analysis.

Future

The only adequate processes which have been operated so far on an industrial scale belong to the solvent extraction category. As a result of this experience, substantial economies can be visualised in future plants of this kind, particularly if through-puts are large. Another factor which is likely to strengthen the case for solvent extraction processes is the unsettled state of fuel-element design. Almost any variety of solid fuel element of a given general type can be accepted for treatment in a solvent extraction plant provided suitable modifications can be made at the decanning and dissolving stage. Nevertheless, specific instances might arise where some other form of process is more appropriate, such as the need for a short decay period for plutonium fuel from fast reactors. Here the savings in fissile material inventory arising from the shorter decay period must be more than sufficient to cover the extra cost of gamma-active fuel-element fabrication which will be required if a high-temperature separation process is used.

In certain types of reactors using liquid fuel, it is proposed to separate the fission products by means of a process which is an integral part of the reactor fuel circuit. In this case, the advantages to be obtained in neutron economy from the rapid elimination of fission product poisons must be set against the higher processing cost in a small plant. Clearly only the simplest kind of operation which can easily be accommodated in the reactor ensemble will be feasible. Where a number of such reactors are grouped together at a large power station a single more elaborate continuous processing unit might conceivably serve them all. In this case it might also be worth while to include the blanket processing plant and any additional facilities required for periodical complete recovery of the core fluid on the same site. As the number of stations generating electricity from nuclear reactors increases, these questions will become more important and it is probable that owing to the complexity of the technical and economic factors, each situation will demand its own solution.

Handling

The necessity for close co-operation between the experimental physicist, the engineer, and the health physicist in the designing of glove boxes was one of the points that emerged during discussion at the recent glove box symposium at Harwell. The range of aspects relevant to glove box design and operation was emphasised by the 51 papers presented and by the discussion provoked by them. However, a clear-cut ruling on the fundamental problem of when a glove box should be used did not seem available and much controversy centred around the subject. One delegate suggested that glove boxes were only necessary when controlled atmosphere was essential. Another view was put by Mr. H. J. Dunster, who was willing to suggest levels of radioactivity at which various substances should be handled in a glove box. These figures are given in the table below.

The figures only apply to pure samples.

For example, if, as is often the case, caesium is contaminated with strontium, then a glove box would be necessary at a much lower level of radioactivity than is indicated.

Material.	Radioactivity level at which normal chemical reactions should be carried out in a glove box.	
	Wet or damp Reactions	Dry Reactions
Plutonium	1-10 mC	10-100 μC
New fission products	10-100 C	0·1-1·0 C
Old fission products..	1-10 C	10-100 mC
Caesium	100-1,000 C	1-10 C

Fuel Processing Techniques

The expanding nuclear power programme has brought with it an increase in the need for means of processing the spent fuel. The lengthy chemical stages in the present solvent extraction methods, and the necessity for a cooling period before such processes can be used, has stimulated research into alternative techniques. A paper presented by Mr. B. A. J. Lister and Mr. P. D. Hey gave an account of a simple melting process; small-scale laboratory experiments had indicated that it gave reasonable decontamination from neutron poisons. The major fission products responsible for poisoning are either volatilised or rise to the surface of the melt as an oxide or carbide slag, by reason of interaction with impurities in the metal or with the walls of the containing vessel. As this type of process was considered sufficiently promising for further development a project (Hotspur) was initiated to continue the experiments at a much higher activity and on a larger scale.

Typical operations that must be carried out are: decanning the fuel element, cutting, melting and casting, dissolving of metal samples, sectioning of metal samples, examination, and decontamination of equipment. A high level of all three types of radioactivity will be present, in particular a gamma activity of 1,000 curies was considered to be the normal upper level of activity for any one experiment. The plant was designed so that operations were separated into individual units, thus enabling maintenance to any one unit while the others were still in use. Five units make up the suite and are respectively for furnace operations, chemical dissolving and dispensing, physical examination, cutting, and storage. The three boxes for the first three operations are connected by a fourth box which contains trolleys for transfer between boxes and storage facilities for small specimens and various specialised items of equipment. The transfer box is connected by a shielded tunnel and conveyor to a pond area, which contains storage space, simple can-opening facilities and a cutting machine. The only entrance to the suite is the conveyor.

Ten inch thick lead shielding is used and manipulations are made by through-the-wall tongs or mechanical drives. The tongs are manipulated through sphere units which enable an included angle of 60 deg. to be covered. The shielding by the sphere unit is, however, not equivalent to 10 in. lead and it is hoped that an improvement will be obtained by the use of uranium spheres, when they become available. The pond is demineralised water contained in a stainless-steel tank 12 ft. long, 4 ft. wide, and 9 ft. deep.

In a review of the engineering design of the suite, presented by Mr. G. E. Simmonds, further details were given. The microscope, shown in Fig. 5, is designed for either a monocular or a binocular head. Adequate shielding is incorporated to prevent radiation damage to the lens assembly and periscopic viewing is used to eliminate radiation from the microscope head. The cost of a single cell with an inner box 5½ ft. by 4 ft. by 3½ ft. high is estimated at £13,600, of which £7,500 is spent on lead and uranium.

Metallography

A paper presented by Mr. E. C. Sykes, Mr. V. J. Haddrell, and Mr. A. W. Elson considered the metallographic examination of radioactive materials. Such operations with ordinary materials are basically simple, but a great measure of skill is necessary. When remote control must be employed apparently simple operations become very complicated. Three sets of apparatus have been developed at Harwell; the highest activity that can be dealt with is 10 curies. None of the three is suitable for alpha-active materials. The 10 curie equipment incorporates a high definition television system for use with a microscope.

It will be apparent from the foregoing remarks that the term glove box is used for very different types of apparatus. There were several proposals at the symposium for alternative names, notably the terms "cell" or "cave" for the larger boxes, typical of frog-suit areas. However, no decisions were reached other than on the desirability of forming a committee to investigate the matter.

Manipulation and Stereoscopic Television

A stereoscopic television camera unit which has been designed specifically for use in nuclear research is shortly to be supplied by Marconi's Wireless Telegraph Company, Limited, to the Atomic Energy Authority's research station at Harwell. The equipment will be used with special remote manipulating equipment for the handling at a distance of dangerous radioactive or toxic materials. Special equipments are at present under development, some of which will be capable of remote manipulation up to distances of half a mile (or more if desired). It is obvious that some form of visual aid is necessary for operations of this kind. Ordinary closed-circuit

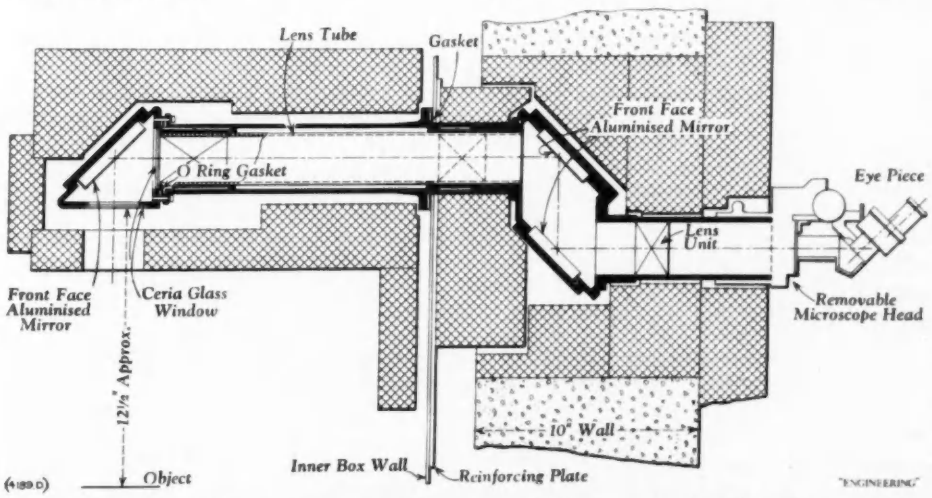


Fig. 5 Microscope for use in conjunction with the Harwell Hotspur suite, in which active materials are handled and treated at high temperatures.

Fig. 6 The Savage and Parsons master-slave manipulator may be used in conjunction with Marconi stereoscopic television to enable relative distances to be judged in the remote handling of radioactive and toxic materials.

television has already been tried, but has proved to have limitations, insofar as the absence of perspective in the screened image makes it difficult for the operator to judge the distance of the manipulator's "hands" from the objects to be handled. With the stereoscopic television now developed by Marconi's, perspective has been restored and the operator sees what appears to be a solid (that is three-dimensional) image.

An example of the remote-handling equipment to be used with the stereoscopic unit is the master-slave manipulator made by Savage and Parsons, Limited, of Watford, to the specifications of the Atomic Energy Authority. This type of manipulator, which is capable of operating through a biological shield up to 6 ft. thick, is controlled by clips attached to the operator's fingers. The movements of the fingers are transmitted through a system of extension rods terminating in a mechanical hand, which reproduces the hand and finger movements of the operator. The manipulator will perform all tasks normally requiring human hands, from lifting gently a delicate piece of apparatus to moving weights, in an emergency of up to 20 lb. Sufficient control over the mechanical hand is obtained to enable such operations as removing the stopper from a bottle and pouring the contents into a beaker to be effected without difficulty, provided, of course, that the operator can see the objects to be manipulated.

The Marconi stereoscopic camera channel consists of two industrial Vidicon cameras, two control units and two display monitors. The cameras are mounted side by side, with their lines of sight inclined so that they intercept at the point of interest. The left-hand camera of the pair (corresponding to the left eye) is connected to one of the monitors, which thus gives a left-eye view of the scene; similarly, the right-hand camera and monitor give a right-eye view. The two monitors are so placed in the display cabinet that the pictures are superimposed by means of a semi-silvered mirror. A vertically polarised polaroid filter covers the face of one screen, while the other is covered by a second polaroid filter which is horizontally polarised. If the composite image is viewed through suitably polarised spectacles a stereoscopic effect is obtained.

Plutonium

There appear to be still unsolved problems on the use of plutonium as a reactor fuel; at least, its properties and cross-sections have not yet been fully established. One difficulty seems to be a positive temperature coefficient, which might lead to instability in fast reactors, but this may largely be related to volume changes arising from thermal expansion. It should be emphasised that these observations are largely a matter of hearsay, and that in any case the initial charge in the Dounreay fast reactor will be uranium 235.

The Dowty hand-held vibrometer employs an adjustable vibrating reed which vibrates at its maximum amplitude when its natural frequency coincides with that of the body against which it is held. The unbalanced pick-up in the foreground is used to convert the instrument into a tachometer.

VIBROMETER AND REVOLUTION INDICATOR

3·5 to 350 Cycles per second

A vibrating-reed hand-held sensitive vibrometer, which can also be used as a revolution indicator, has been introduced by Dowty Nucleonics Limited, Brockhampton Park, Andoversford, Gloucestershire. It operates over the range 3½ to 350 cycles per second, and enables each frequency to be segregated in the presence of other frequencies.

The reed vibrates at maximum amplitude when its natural frequency coincides with that of the body against which it is held. By applying the vibrometer at various points and "tuning-in" the reed for maximum amplitude, the sources of vibration can be traced. The thin steel reed is wound from the instrument through a "Nodegate," by a hand-knob which operates a built-in reduction drive. Variation of its cantilevered length determines the reed's natural frequency of vibration, which is automatically indicated on the scale for any reed setting.

The vibrometer may also be readily used as an accurate hand-held revolution indicator by applying to it a rotating unbalanced force at the frequency of the rotating shaft, and determining this frequency. This is accomplised by using a slightly unbalanced pick-up, seen in front of the vibrometer, which fits into, and revolves inside the hollow vibrometer spindle with the rubber drive-cone protruding about 3 in. The reed is tuned in the normal way until the unbalanced rotating force resonates the reed at maximum amplitude. The dial is then read for frequency, and this figure indicates directly the rotational speed of the shaft. Tuning is extremely fine, and the resulting accuracy is high.

Among the applications cited by the manufacturers are the analytical diagnosis of vibration problems and the accurate speed indicating of electric motors, air compressors, pumps, line shafting, etc., where the vibration is sufficient to use the instrument as a vibrometer. It is particularly useful for accurate speed indicating of small electric motors having insufficient power to drive a tachometer. In this case the slight out-of-balance force is introduced into the motor, if necessary, by the application of plasticine, or a small unbalanced pulley on the motor spindle. The vibrometer is held against the motor and the frequency of the vibration measured. For determining the speed of pneumatic road breakers, drills and compressed-air motors the reed of the vibrometer is held in the exhaust and tuned to the frequency of the pulsations. In a similar way the instrument can be used in the exhaust system of internal combustion engines. The speed of a motor car engine can be measured very rapidly by this method.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

BIRMINGHAM
"Earth Leakage Protection in Domestic and Similar Installations," by E. Coleman. Birmingham Branch. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham, 2. Wed., Mar. 13, 7.15 p.m.

BRADFORD
"Uses of X-Rays," by F. Hudson. Bradford Branch. Royal Infirmary, Bradford. Wed., Mar. 13, 8 p.m.

OXFORD
"Specialised Spot Welding," by C. G. Aldridge. Oxford, Reading and Districts Branch. Regents Park College, Pusey-street, Oxford. Sat., Mar. 16, 6.30 p.m.

SOUTHSEA
"Co-ordination Between Lighting and Interior Decoration in Industry," by Raymond Pye. Portsmouth Branch. Royal Beach Hotel, Southsea. Thurs., Mar. 14, 8 p.m.

Chemical Engineering Group

LONDON
"A Survey of Industrial Filtration," by A. P. Hosking and K. C. Salter. Society of Chemical Industry, 14 Belgrave-square, S.W.1. Mon., Mar. 11, 5.30 p.m.

Chemical Society

LONDON
"Chemical Problems Relating to the Origin of the Earth," by Professor H. C. Urey. Royal Institution, Albemarle-street, W.1. Thurs., Mar. 14, 7.30 p.m.

GLOUCESTER
"Use of Radio-Isotopes in Industry and Medicine," by Dr. G. B. Cook. Bristol Branch. Technical College, Brunswick-road, Gloucester. Thurs., Mar. 14, 7 p.m.

LEEDS
"Automatic Control and the Chemist," by the Earl of Halsbury. Leeds Branch. Chemistry Lecture Theatre, The University, Leeds. Mon., Mar. 11, 6.30 p.m.

Illuminating Engineering Society

LONDON
"Visibility on the Road," by A. J. Harris. Federation of British Industries, 21 Tothill-street, S.W.1. Tues., Mar. 12, 6 p.m.*

BRISTOL
"A Critical Analysis of Lighting Equipment and Its Maintenance," by J. Mortimer Hawkins and C. J. Veness. Bath and Bristol Centre. Royal Hotel, Bristol. Tues., Mar. 12, 7 p.m.

SHEFFIELD
"Light and Vision," by H. Moore. Sheffield Centre. Medical Library, The University, Western Bank, Sheffield 10. Mon., Mar. 11, 6.30 p.m.

Incorporated Plant Engineers

LIVERPOOL
Annual General Meeting. Merseyside and North Wales Branch. Exchange Hotel, Liverpool. Mon., Mar. 11, 7.15 p.m.

MANCHESTER
Annual General Meeting. Manchester Branch. Engineers' Club, Albert-square, Manchester. Tues., Mar. 12, 7.15 p.m.

NEWCASTLE-UPON-TYNE
Annual General Meeting. "Coal and Its Handling," by R. H. Furness. North East Branch. Roadway House, Oxford-street, Newcastle-upon-Tyne. Thurs., Mar. 14, 7 p.m.

PETERBOROUGH
Annual General Meeting. Peterborough Branch. White Lion Hotel, Church-street, Peterborough. Thurs., Mar. 14, 7.30 p.m.

Institute of Fuel

LONDON
"The Work of the British Coal Utilisation Research Association," by M. V. Murray. Institution of Civil Engineers, Great George-street, S.W.1. Wed., Mar. 13, 5.30 p.m.*

Institute of Marine Engineers

LONDON
"The Harland and Wolff Pressure-Charged Two-Stroke Single-Acting Engine," by C. C. Pounder. Tues., Mar. 12, 5.30 p.m.*

ABERDEEN
"The Wire Mill," by R. Taylor. Scottish Section. Robert Gordon's College, Aberdeen. Fri., Mar. 15, 7.30 p.m.

EDINBURGH
"The Wire Mill," by R. Taylor. Scottish Section. Grosvenor Hotel, Edinburgh. Wed., Mar. 13, 7.30 p.m.

NEWCASTLE-UPON-TYNE
"Combating Cylinder Wear and Fouling in Large Low-Speed Diesel Engines," by M. J. van der Zijden and A. A. Kelly. North East Coast Section. Stephenson Building, King's College, Claremont-road, Newcastle-upon-Tyne. Thurs., Mar. 14, 6.15 p.m.*

Institute of Metals

BIRMINGHAM
Annual General Meeting and Chairman's Address. Birmingham Local Section. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Thurs., Mar. 14, 6.30 p.m.

GLASGOW
"Production and Uses of Rare Metals," by Dr. J. C. Chaston. Annual General Meeting. Scottish Local Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Mon., Mar. 11, 6.30 p.m.

SWANSEA
"Clad Metals," by Professor A. R. E. Singer. South Wales Local Section. University College, Singleton Park, Swansea. Tues., Mar. 12, 6.45 p.m.*

Institute of Physics

LONDON
Discussion on "Measurements of the Elastic and Plastic Properties of Coal." Non-Destructive Testing Group. Fri., Mar. 15, 6.30 p.m.*

EDINBURGH
"Velocity of Light: A Survey of the Measurement Technique," by Dr. L. Essen. Scottish Branch. Natural Philosophy Department, The University, Edinburgh. Mon., Mar. 11, 7.15 p.m.

GLASGOW
"Velocity of Light: A Survey of the Measurement Techuique," by Dr. L. Essen. Scottish Branch. Natural Philosophy Department, The University, Glasgow. Tues., Mar. 12, 7.15 p.m.

SHEFFIELD
"The Properties of Materials in Nuclear Reactors," by Dr. P. Murray. Annual General Meeting. Yorkshire Branch. The University, Sheffield. Wed., Mar. 13, 5 p.m.

Institute of Road Transport Engineers

BIRMINGHAM
"Gas Turbine Development for Road Transport," by P. A. Phillips. Midlands Centre. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Tues., Mar. 12, 7.30 p.m.

MANCHESTER
"Petrol Injection," by J. N. Morris. East Regional Centre. Houldsworth Hall, 90 Deansgate, Manchester. Mon., Mar. 11, 7.30 p.m.

Institution of British Agricultural Engineers

LONDON
"Slip Clutches and Mechanical Safety Devices," by F. Lee. Tues., Mar. 12, 5.30 p.m.*

NEWCASTLE-UPON-TYNE
"Farming in the Sudan," by J. L. Manson. Northern Centre. Offices of the North Eastern Electricity Board, Carliol House, Newcastle-upon-Tyne. Mon., Mar. 11, 6.45 p.m.

Institution of Chemical Engineers

MANCHESTER
"Disposal of Long-Lived Fission Products," by J. R. Grover. North Western Branch. College of Technology, Manchester. Thurs., Mar. 14, 7 p.m.

Institution of Civil Engineers

LONDON
"Site and Laboratory Work in Connection with the Development of Long Welded Rail Track on the Western Region of British Railways," by K. D. Rhodes and M. R. Dart. Railway Division. Tues., Mar. 12, 5.30 p.m.*

BELFAST
Discussion on "Contractor and Engineer—The Contractor's Viewpoint," opened by W. J. Shirley. Northern Ireland Association. Queen's University, Belfast. Mon., Mar. 11, 6.30 p.m.

EDINBURGH
"Water Pollution Prevention in Scotland," by J. B. Dempster. Edinburgh and East of Scotland Association. North British Hotel, Edinburgh. Wed., Mar. 13, 6 p.m.

LINCOLN
"Recent Developments in Tunnelling," by O. Dawson. East Midlands Association. Technical College, Cathedral-street, Lincoln. Tues., Mar. 12, 6.15 p.m.

MIDDLESBROUGH
"Work of the Hydraulics Research Station of the D.S.I.R.," by F. H. Allen. Northern Counties Association. Cleveland Scientific and Technical Institution, Middlesbrough. Wed., Mar. 13, 6.15 p.m.

NEWCASTLE-UPON-TYNE
"Acorn Bank and Radar Opencast Coal Sites," by P. J. Sellier. Northern Counties Association. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Tues., Mar. 12, 6.15 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
Chemical Engineering Group, 16 Belgrave-square, London, S.W.1. (BELgravia 3647.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 17 Belgrave-square, London, S.W.1. (BELgravia 3291.)
Institute of Physics, 47 Belgrave-square, London, S.W.1. (SLOane 9806.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of British Agricultural Engineers, 6 Buckingham-gate, London, S.W.1. (TATe Gallery 8589.)
Institution of Chemical Engineers, 16 Belgrave-square, London, S.W.1. (BELgravia 3647.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineers-in-Charge, 100 Earlsfield-road, London, S.W.18. (BATtersea 1394.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechancial Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Railway Signal Engineers, Euston House, Eversholt-street, London, N.W.1.
Institution of the Rubber Industry, 4 Kensington Palace-gardens, London, W.8. (BAYswater 9101.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool 2. (Central 3717.)
Manchester Association of Engineers, 18 Booth-street, Manchester 2. (Central 1717.)
Newcomen Society, Science Museum, Exhibition-road, London, S.W.7. (KENsington 1793.)
North East Coast Institution of Engineers and Shipbuiders, Bolbec Hall, Newcastle-upon-Tyne 1. (Newcastle 20289.)
Reinforced Concrete Association, 94-98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Sheffield Metallurgical Association, 66 Ringstead-crescent, Sheffield 10. (Sheffield 62144.)

Institution of Electrical Engineers

LONDON
Discussion on "Simple Approaches to the Understanding of Commutation," opened by Professor A. Tustin. Education Discussion Circle. Mon., Mar. 11, 6 p.m.*
"An Analogue Computer for Nucelar Power Studies" and "The Application of Analogue Methods to Compute and Predict Xenon Poisoning in a High-Flux Nuclear Reactor," by G. J. R. MacLusky. Measurement and Supply Sections. Joint meeting with the British Nuclear Energy Conference. Tues., Mar. 12, 5.30 p.m.*
"Electrical Equipment for Rectifier Locomotives," by H. B. Calverley, E. A. Jarvis and E. Williams; and "Circuit Calculations for Rectifier Locomotives and Motor Coaches," by T. E. Calverley and D. G. Taylor. Utilization Section. Thurs., Mar. 14, 5.30 p.m.*
BELFAST
"Potentialities of Railway Electrification at Standard Frequency," by E. L. E. Wheatcroft and H. H. C. Barton. Northern Ireland Centre. Queen's University, Belfast. Tues., Mar. 12, 6.30 p.m.
BRIGHTON
"Heat Pumps," by Miriam V. Griffith. Southern Centre. Technical College, Brighton. Wed., Mar. 13, 6.30 p.m.
CARDIFF
"Transistor Power Amplifiers," by R. A. Hilbourne and D. D. Jones; and "Transistor D.C. Converters," by L. H. Light and P. M. Hooker. Western Centre. South Wales Institute of Engineers, Park-place, Cardiff. Mon., Mar. 11, 6 p.m.*
MALVERN
"Vacuum Techniques," by D. J. Taylor; "Temperature Control," by J. P. King; and "Cutting of Semi-Conductors," by J. R. Walford. South Midland Centre. Winter Gardens, Malvern. Mon., Mar. 11, 6 p.m.*

Institution of Engineers-in-Charge

LONDON
"Atomic Energy," by J. A. Dixon. St. Bride Institute, Bride-lane, E.C.4. Wed., Mar. 13, 6.30 p.m.*

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Ship Repairing," by D. H. Sword. Tues., Mar. 12, 6.30 p.m.*

Institution of Heating and Ventilating Engineers

LONDON
"Some Design Considerations of Floor Heating," by E. Danter. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Mar. 13, 6 p.m.*
BIRMINGHAM
Annual General Meeting and Film Evening. Birmingham Branch. Birmingham Exchange and Engineering Centre, Stephenson-place, Birmingham. Tues., Mar. 12, 6.30 p.m.
MANCHESTER
Annual General Meeting and Chairman's Address. Manchester Branch. Engineers' Club, Albert-square, Manchester. Fri., Mar. 15, 6.30 p.m.

Institution of Locomotive Engineers

GLASGOW
"Locomotive Boiler Feed Water Treatment," by A. J. Parsons and J. S. Hancock. Scottish Centre. St. Enoch Hotel, Glasgow. Wed., Mar. 13, 7 p.m.

Institution of Mechanical Engineers

LONDON
"Transmission Developments for Public Service and Heavy Goods Vehicles," by E. Gordon Wilson. Automobile Division. Tues., Mar. 12, 6 p.m.*
Discussion on "Factors in the Handling of Lubricants." Lubrication Group. Fri., Mar. 15, 6.45 p.m.*
LINCOLN
"The Influence of the Gas-Turbine Axial-Flow Aero Engine on Blade Manufacturing Methods," by R. R. Whyte. East Midlands Branch. Technical College, Lincoln. Wed., Mar. 13, 7.30 p.m.
NORWICH
"The United Kingdom Atomic Energy Project," by Dr. J. V. Dunworth. Eastern Branch. Assembly House, Norwich. Thurs., Mar. 14, 7.30 p.m.

Institution of Production Engineers

CHATHAM
"Full Employment Incentives and Productivity," by J. Ayres. Rochester Section. Sun Hotel, High-street, Chatham. Thurs., Mar. 14, 7.30 p.m.
EDINBURGH
Discussion on "Implications of Automation." Annual General Meeting. North British Hotel, Edinburgh. Edinburgh Section. Wed., Mar. 13, 7.30 p.m.

Institution of Railway Signal Engineers

YORK
"Major Signalling Schemes," by G. S. Wilkinson. Signalling School, Toft Green, York. Wed., Mar. 13, 5.30 p.m.*

Institution of the Rubber Industry

LONDON
"Petroleum as a Raw Material for Synthetic Rubber," by A. A. Appleton, at 5.30 p.m.* "Fluorinated Elastomers," by Professor M. Stacey, at 7 p.m. 26 Portland-place, W.1. Tues., Mar. 12.

Junior Institution of Engineers

LONDON
"Astronautics To-Day and To-Morrow," by G. V. E. Thompson. Fri., Mar. 15, 7 p.m.*

Liverpool Engineering Society

LIVERPOOL
"Modern Roadways," by J. A. Proudlove. Wed., Mar. 13, 6 p.m.

Manchester Association of Engineers

MANCHESTER
"Industrial Television," by J. E. H. Brace. Engineers' Club, Albert-square, Manchester. Fri., Mar. 15, 6.45 p.m.

Newcomen Society

LONDON
"F. W. Lanchester, F.R.S.: His Life and Work," by George H. Lanchester. Wed., Mar. 13, 5.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
"The Stork Engine," by A. Hootsen. Literary and Philosophical Society's Apartments, Newcastle-upon-Tyne. Mon., Mar. 11, 6.15 p.m.

Reinforced Concrete Association

LONDON
"Reinforced Concrete Problems on the Gold Coast," by F. S. B. Jacobson. 11 Upper Belgrave-street, S.W.1. Wed., Mar. 13, 6 p.m.*

Royal Aeronautical Society

LONDON
"High-Temperature Materials for Engines," by E. R. Gadd. Tues., Mar. 12, 7 p.m.

Sheffield Metallurgical Association

SHEFFIELD
"Hot Planetary Mill," by H. M. Waltl. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield. Tues., Mar. 12, 7 p.m.

SAFEGUARDING UNATTENDED EQUIPMENT

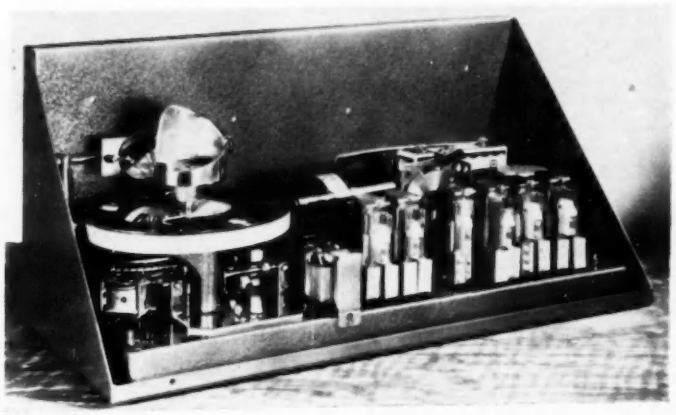
Machine Telephones Details of Failures

Equipment that operates unattended usually has built-in alarm systems that attract the attention of local staff when set off. However, it is often uneconomical to have staff on a site merely waiting for a fault to occur and some other solution would appear desirable. An efficient way of tackling the problem is presented by the tele-alarm unit manufactured by the Auto Call Company, Limited, Security House, 40-42 Parker-street, London, W.C.2.

The machine, which is Post Office approved, is arranged to call out over the normal telephone system from the unattended premises to the control room. If a fault occurs the unit dials the number it requires and passes on a message, giving details of the fault, by playing a wax recording. The message is repeated over a period of 4 minutes so as to give it ample time to be received by the control room operator. On receipt of the message, the operator has only to telephone back to the number given in the recording and the machine automatically acknowledges his call, cancels all further messages, and resets.

Should the call not be answered during the first 4 minutes (the line might be engaged) the machine disconnects itself from the telephone line and waits for a period of four minutes, after which it calls for a further four minutes. This procedure is repeated four times, giving an overall period of 28 minutes. It is considered unlikely that the call will fail to get through in this time.

The unit, shown in the illustration, is self-contained and is normally housed in a steel box. A 6 volt electric motor drives the 6 in. record turntable at 78 r.p.m. and a special pick-up mechanism provides automatic repeat playing. The pick-up itself is a carbon type powered by a 4½ volt battery. A dial wheel, cut to individual requirements, operates a contact assembly to give the necessary dialling impulses (10 per sec., 67 per cent. break—37 per cent. make). To achieve the timing of the repeated calls a relay capacitor circuit, driven from a 12 volt accumulator, is used which feeds impulses at 25 second intervals to another relay operating on an electromagnetic ratchet motor. On the motor spindle is mounted a notched wheel with attendant contact breakers which control both the timing and the duration of calls. Another relay circuit accepts incoming calls, but only during intervals in the operating cycle. This relay causes the ratchet motor to move round rapidly, cancelling any further outward calls. After a short delay the speech unit plays for a period of one minute to acknowledge the incoming call; for this operation dialling is suppressed. Following acknowledgment the machine stops and disconnects from the telephone line; but one relay remains held in until the alarm condition is removed. On rectification of the fault this relay releases and resets the whole machine in readiness to report further details.



This view of the tele-alarm unit shows the 6 in. turntable with a wax recording on it. The relays at the front of the chassis control the timing. The pick-up is a carbon type powered by a 4½ volt battery.

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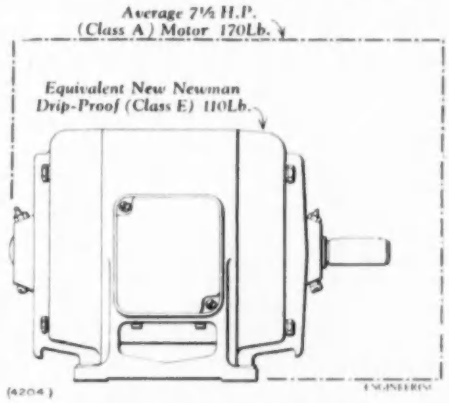
SMALLER ELECTRIC MOTORS

Before the recent draft British Standard specifications for class E insulation of motors appeared there was little to chose, in price, between totally enclosed and drip-proof motors. For this reason totally enclosed motors were generally favoured, since they offered the advantage of complete protection for very little extra cost.



Use of class E insulation has permitted a considerable reduction in the size of motors while retaining the same rating.

However, the new draft specifications CW(ELE)6246 (dimensions) and BS. 2613 (electrical) allow considerable difference in price between the two types of construction. Newman Industries, Limited, Yate, Bristol, have been quick to exploit this advantage. Their new range of drip-proof motors, from ½ to 50 h.p., are considerably reduced in size and cost, compared with totally enclosed motors using class A insulation. The significant difference between the two classes is that the permitted rotor temperature rise for class A insulation is 40 deg. C., whereas that for class E is 65 deg. C. The illustration gives some idea of the space saved on a 7½ h.p. motor.

In addition to improving the individual motor design, particularly the internal ventilation system, Newman Industries have also reorganised their plant. The factory is being split up into three self contained units, each unit dealing with a particular size range of motors.

VARIATIONS ON THE ENGINE THEME

By Gordon Wilkins

The rapidly widening gulf between American and British standards of car performance poses a difficult problem for British manufacturers trying to sell high-performance cars in the United States. Alongside the cheap American popular car with an engine of 4½ to 5 litres, developing from 180 to 250 b.h.p. gross, with a torque of 250 to 300 lb. ft., the performance of many European so-called high-performance models appears pathetic, particularly in acceleration from a standstill to 60 m.p.h. Jaguar have tackled this problem with a project long held in reserve for the purpose, putting the 3·4 litre engine in the 2·4 litre car. Thus equipped, it is said to go from standstill to 60 m.p.h. in 11·7 seconds, which will just about enable it to keep up with the local leviathans.

The new engine probably adds about 60 lb. to the weight on the front end, weight distribution now being 56 per cent. on the front. This will be increased when the automatic transmission is fitted, and it will be surprising if the handling of the car on corners is as attractive to European drivers as that of the 2·4 litre, although this will probably not excite much notice in comparison with the nose-heavy "sleepy" cars in the United States where most of the new models will be sold. No increase has been made in the braking capacity, although disc brakes have been tried out on this model for some time.

Clearly Jaguar and other British manufacturers will be under continuing pressure to make further increases in engine size for the American market. The engine of the Jaguar sports racing model has been experimentally enlarged to 3·8 litres in the United States, and it seems probable that future racing models appearing over there will employ the enlarged engine, which is said to produce 300 b.h.p.

AUSTIN TURBINE: A NEW PHASE

Gas turbine development is being taken seriously at the Austin Motor Company. The first phase, consisting of intensive rig testing and development of individual components, supplemented by road testing on a converted Sheerline saloon is now ended. This programme was referred to in ENGINEERING on December 28, 1956, page 802. The next stage is the construction of a new prototype car specifically designed for turbine propulsion, and this has now begun.

Meanwhile Austin have released some background information on their design policy to supplement the fragmentary progress reports which have been issued from time to time. With a two-stage centrifugal compressor, driven by a three-stage turbine, followed by a single-stage power turbine, the Austin unit is one of the most complicated so far produced for automobile propulsion, but complication brings in its train the ability to obtain good efficiencies at the low compressor speed of 22,000 r.p.m., and the T_{max} of 800 deg. C. opens the way to the use of fairly inexpensive blade materials, or offers a long life with more costly materials. It has also been possible to use turbine blades of constant section without twist; in fact all blades are of the same section, varying only in length, and turbine wheels are of the same form except for details of attachment to the shafts. Low speeds, and multiple stages have also kept root stresses down, allowing the blades to be pinned in a groove in the periphery of the disc, and avoiding the conventional fir-tree root.

The compression ratio of 4 : 1 is not particularly high, and the unit generally is designed to yield high thermal efficiency at part load, the most prevalent condition in automotive use.

The approach has much in common with that of the big American manufacturers, based on the view that it is no longer enough to design a reliable and efficient turbine; it must give acceptable efficiency at an acceptable production cost.

GOLIATH 1100

Up to now the Goliath has been the least known car of the Borgward group, that extraordinarily successful family concern in North Germany. It lacked the mass appeal of the little Lloyd which holds a steady place in the top four in German sales, and never matched the performance and appearance of the Borgwald Isabella.

The new Goliath 1100 has—

—a flat-four water-cooled engine—

The first post-war Goliath, with a 688 c.c. two-stroke engine driving the front wheels, was underpowered; an effort was made to give it more life when the GP 900E was brought out in 1955 with a fuel injection two-cylinder engine of 886 c.c., but it still failed to match the popularity of the three-cylinder DKW.

Now the Goliath has been redesigned, with a flat four-stroke 1100 c.c. engine driving the front wheels, a formula not seen in a popular small car since the interesting but overweight Cemsa Caproni prototype was shown just after the war. The new engine is largely constructed of light alloys; maximum power is unchanged, but there is a useful increase in torque and a slight reduction in engine revolutions for a given road speed. Transmission is through a four-speed all-synchromesh gearbox, and brakes are bigger than before.

The engine, carried on a three-point mounting ahead of the front wheels, drives to the four-speed all-indirect all-synchromesh gearbox just behind the differential. Light alloy is used for crankcase, cylinder blocks and heads, with inserted wet cast-iron cylinder liners, and inserted valve guides and seats. It is an "oversquare" unit with big bores and a short stroke (74 by 64 mm.) which gives space for good steering lock and a small turning circle (35 ft.). Compression ratio is 7·3 : 1 and maximum power is 40 b.h.p. at 4,250 r.p.m., maximum torque being 59·2 lb.-ft. at 2,750 r.p.m. Weight of the power unit is 196 lb.

The body is a unit structure gaining strength from a welded-in tubular backbone. The front suspension now employs a single transverse leaf spring, and a single wishbone at each side. At the rear is a rigid dead axle of half elliptic springs. Centralised one-shot chassis lubrication is a standard feature. The car has a wheelbase of 89·3 in. and dry weight is given as 1,895 lb.

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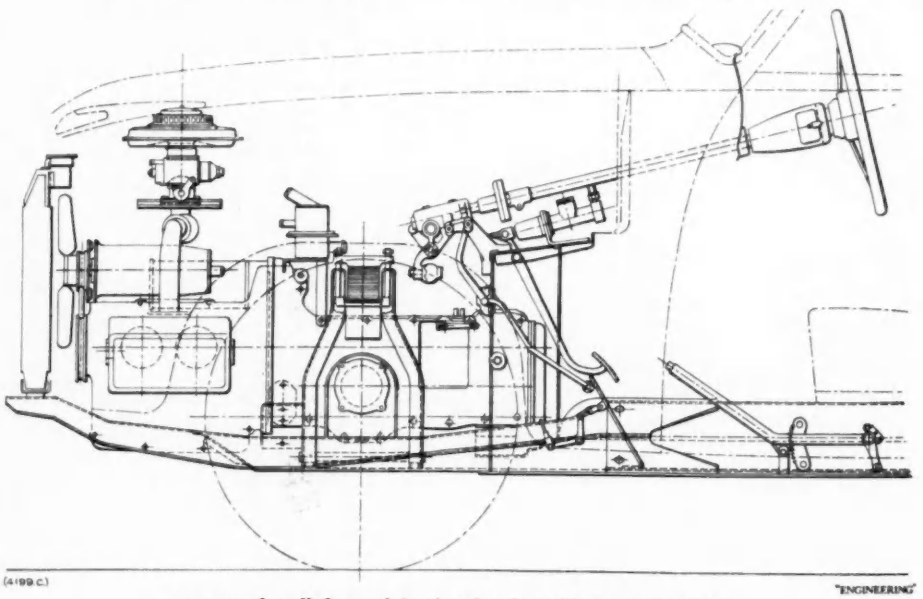
PAPERS BY YOUNG ENGINEERS

British Association Meeting in Dublin

In accordance with the custom which has developed during recent years, one of the sessions of Section G (Engineering) at the meeting of the British Association, to be held in Dublin from September 4 to September 11, will be devoted to the reading of papers by young engineers and engineering students. Anyone desirous of presenting such a paper, which should be short, is invited to communicate as soon as possible with the Recorder of Section G, Professor J. Greig, Department of Electrical Engineering, King's College, Strand, London, W.C.2, from whom full particulars can be obtained.



—arranged well forward in the chassis, with front-wheel drive.

In Parliament

NO CAR INDUSTRY INQUIRY

A resolution was moved in the House of Commons recently by Mr. James Johnson (Labour) calling upon the Government to appoint an independent commission to inquire into the present difficulties and future prospects of the motor-car industry. He said that there had been an overwhelming decline in Britain's share of motor-car markets abroad. Men in Coventry, Leamington and Rugby who had lost their jobs in car factories were not going into other skilled employment, but were becoming postmen and bus conductors. It represented quite a fall in their wages.

The motion was seconded by Miss Elaine Burton (Labour), who asked whether the Government wanted to maintain this country's position—she was not sure whether it still held—as the greatest car-exporting country in the world. The employment and manpower situation in the industry was one of its major difficulties at the present time. Another point that had to be considered, at any rate so far as the home market was concerned, was the impact of purchase tax.

Mr. William Shepherd (Conservative) took the view that there was no case for a Government inquiry, whether public or not, as a good deal of information was already available. Although the industry had had a substantial reverse, there were many things on the credit side of the picture, including its remarkable record of achievement in the export trade.

He pointed out that the Volkswagen, to which frequent reference had been made in the debate, had been originally designed by an Englishman and that, in his view, it was a very old-fashioned car. He did not think it a very distinguished vehicle, although it was a robust machine which could run for 60,000 or 70,000 miles without a major overhaul. The steering was bad and he considered the back-seat accommodation much more uncomfortable than that of the Jaguar, to which reference had also been made.

In spite of its need for being re-bodied the Morris Minor was, in his view, the best all-round small car produced since the war. There was still room for a smaller car for the European market and to develop a new market at home. On this point Mr. Charles Pannell (Labour) agreed. He said that the Morris Minor had been made for the British market and made superlatively well.

GOVERNMENT'S VIEW

Speaking for the Government, Mr. F. J. Erroll, the Parliamentary Secretary to the Board of Trade, said that the rate of purchase tax on cars had not changed very much during the last five years and could hardly be described as the factor dominating the level of vehicle sales.

Any public speculation about the possibility of a reduction in tax would tend to stop sales altogether and do much harm to the motor-car industry.

The decline in sales to the home market had not led to any increase in the volume of exports, but a higher percentage of overall production had been exported. In 1956, exports from Britain were valued at £113 million and, in that year, sales in the North American market were 65 per cent. above the level for the preceding year. During the past year, the number of workers employed in the manufacture of motor vehicles, parts and accessories declined by nearly 50,000, from a total of more than 500,000 at the end of 1955. It was estimated that, for the week ended February 16 last, there were about 35,000 persons on short-time. On the other hand, two of the principal manufacturers had resumed full working at the end of January. This confident, virile industry had indeed experienced a set-back, but the decline had been arrested and the average weekly rate of production in January and during the first two weeks in February last was higher than in December, 1956. The suggestion for an independent inquiry was not new. It was difficult to see how the setting up of an inquiry could be justified.

Later, Mr. Robert Carr, the Parliamentary Secretary to the Ministry of Labour and National Service, drew attention to the powers possessed by the Government, by means of loans and other grants, to assist people to move from one area to another in connection with new employment requirements. These powers were the same as those possessed by the Labour Government and the present Government was using them in the same way. The Minister of Labour had given assurances on several occasions that he would keep those powers and their adequacy under constant review.

The debate came to an end under the four o'clock rule.

OPPOSITION TO TRADE UNIONS

There was a short discussion last Friday on the Bill introduced by Mr. Ian Mikardo (Labour) to invalidate rules of friendly societies which discriminate against the membership of trade unions. When the measure was read for the first time, Mr. Mikardo pointed out that there were a few instances where the resistance which was formerly shown by some employers to the growth of trade unions among their shop-floor workpeople had been transferred into resistance to the spread of trade unionism among their white-collar employees. Of themselves, these bodies were worthy institutions. Employers, however, nominated their foremen and other personnel to membership of the societies; but only on condition that they were not, or did not remain, members of a trade union.

Last Friday, the motion for the second reading of the Bill was opposed by Mr. Dudley Williams (Conservative). He said that there had been many Bills of that nature and many discussions, and that he thought that most Members were familiar with the ideas lying behind such measures. It was his view that it was not the function of Parliament to do everything it could to restrict the activities of the people of this country. He thought it important that, if there were to be Bills to restrict the association of people, or such organisations as trade unions, they should not be introduced as Private Members' Bills.

Members were aware that there existed an association which catered for a supervisory class of employee. It gave them certain benefits, including a form of insurance, which were confined to persons of their grade. One of the conditions of being a member of this association was that the member concerned should not belong to any other trade union. In reply to an interjection by Mr. Mikardo, he said that he maintained that the association to which he had referred was a trade union, in spite of its not being affiliated to the Trades Union Congress.

At this stage the debate was adjourned, under the four o'clock rule, until to-day.

AIRCRAFT FOR THE R.A.F.

Development of the English Electric Company's P.1 fighter aircraft is stated to be proceeding satisfactorily. In reply to Mr. George Brown (Labour), who raised the matter, Mr. Aubrey Jones, the Minister of Supply, stated that the delivery of the development batch of these aircraft would begin this year and that an intensive programme of flight testing would follow. A production order for the P.1 aircraft had been placed, but it would not be in the public interest to disclose the size of that order or to state when these aircraft were expected to be taken into service.

Work on the development of the Beverley transport aircraft, Mr. Jones said, was continuing, with a view of overcoming the difficulties which came to light during the intensive Royal Air Force flying trials on these aircraft, and certain improvements were being effected. As had been previously stated, the development of these aircraft had not been more difficult than expected, seeing that they comprised a completely new engine and airframe combination. Nineteen of the aircraft had so far been delivered to the R.A.F. and further deliveries were being made.

GUIDANCE ON PREVENTING FIRES

Mr. Maurice Edelman (Labour) questioned the Home Secretary as to what safety precautions had been recommended by his Department to engineers and builders engaged on factory construction. He drew attention, in particular, to the fire at the Nash-Kelvinator works at Crewe in September, 1956, where bituminous roof coverings undercovered with fibre insulating board caught fire in circumstances similar to those which arose recently at the Coventry factory of Jaguar Cars Limited. (An account of the Jaguar fire was given in ENGINEERING of February 22, page 232.)

Mr. R. A. Butler said that no advice had been issued by Government Departments to engineers and builders as a direct result of the fire at the Nash-Kelvinator works. A great deal of guidance about both fibreboard and roof coverings had been made available by various Departments in their publications, as well as by fire brigades, and by voluntary organisations such as the Fire Protection Association.

Fifty Economic Facts

A plea was put forward by Mr. E. S. T. Johnson (Conservative) that factual information regarding the United Kingdom economy should be made available to British business men travelling overseas, so that they might be in a position to impart the facts to influential people in other countries. Dr. Charles Hill, the Chancellor of the Duchy of Lancaster, said that a booklet on these lines, entitled "Fifty Facts About Britain's Economy" had been prepared by the Central Office of Information for the use of overseas departments of the Government. Copies had been circulated to all British information posts abroad. The Board of Trade and the Federation of British Industries would gladly make copies available on request to business men travelling abroad.

Steel Plate Shortage is World Wide

Firms in Lowestoft engaged in shipbuilding and ship repairing have had difficulty in obtaining their requirements of steel plates and heavy sections, and Mr. T. G. D. Galbraith, Civil Lord of the Admiralty, stated that one Lowestoft firm had imported a substantial proportion of its supplies during last year. There was a world shortage of steel plates, the Minister told Mr. Edward Evans (Labour), and, consequently, the shipbuilding and ship-repairing industries in Britain had shared in the difficulties that that situation had created.

Diesel Engines on British Railways

Mr. Harold Watkinson, the Minister of Transport and Civil Aviation, told Mr. Roy Mason (Labour) that one of the effects of the recent fuel shortage had been to restrict the introduction of further Diesel-engined services on British Railways to urgent requirements. As to the introduction of Diesel engines on railway branch lines, there was at present no scheme for a Diesel-operated service between Barnsley and Leeds, but Diesel engines for other new services either had been, or would be, introduced in the West Riding of Yorkshire this year, as planned.

Jet Aircraft Flying Costs

Mr. Geoffrey de Freitas (Labour) inquired about the cost per hour of flying a single-engined jet aircraft. He was informed by Mr. George Ward, the Secretary of State for Air, that the cost varied widely according to the type of aircraft. In the United Kingdom the cost, on the average, was about £110 an hour.

Supply of Technical Teachers

According to a reply by Sir Edward Boyle, Bt., Parliamentary Secretary to the Ministry of Education, to Mr. R. Moss (Labour), the report of the committee set up last year to investigate the whole problem relating to the supply and training of technical teachers is expected shortly. The chairman of the committee is Dr. Willis Jackson, F.R.S., M.I.E.E., F.Inst.P.

THE HUMAN ELEMENT

The Devil and the Deep Blue Sea

A policy statement has been issued by the Association of Supervisory Staffs, Executives and Technicians dealing with automation. One would expect a responsible view to come from such a body on this subject and this has in fact happened. The association points to the signs which are multiplying that the Continent and the United States are going ahead with automation more rapidly than this country. They emphasise the dangers of such a situation.

The danger is indeed a substantial one. There is now some prospect that the European Common Market will come into existence over the next few years in a form which bears some relation to the draft which has come out of the Customs Union discussions. If and when it does, the Western European market will consist of 240 million people. The opportunities which will exist for specialisation and mass production should be considerable. Under such conditions there are bound to arise new opportunities for using the techniques of automation intelligently. This country must be at the forefront of such a development.

It is all too easy to see in automation and the European Common Market an attack on the organised British worker which must be resisted. It should, however, be a challenge to adopt the new techniques and opportunities from the start. If this is not done the British working man might yet find himself caught between, say, highly specialised German industry employing automation methods and cheap Italian labour. This union has done a good job in drawing attention to the need to go ahead quickly and mould the opportunity before circumstances in their turn mould the prospects of the British worker.

One Man Court

One man, Lord Cameron, has been entrusted by the Minister of Labour, Mr. McLeod, with the inquiry into the Briggs dispute. He will be assisted by four assessors—two from each side—but how far he will inquire and what recommendations he will put forward are for him alone to decide. No-one doubts the seriousness of the situation, the dismissal of the offending shop steward and the clamorous insistence for his reinstatement are but the symptoms of the deep disquiet that exists and has existed in the plant for years.

The roots of this may lie in the attempt by the Ford management when they took over in 1953 to introduce strict discipline, coupled with relatively high pay, which produced good and hard work at the Ford plant. They may lie further back, perhaps too far to be clearly identified. The fact that workers last week-end refused to support a resolution by their shop stewards that a strike should be called unless Mr. McLoughlin were reinstated immediately suggests that the stewards may have over-played their hand.

This is a strike no-body wants. The spring is a season of high demand for motor vehicles and, traditionally, one during which relatively very high earnings can be won. If the demand cannot be met the company are likely to lose ground to their competitors. Lord Cameron is therefore operating under favourable conditions. This was shown by the eagerness with which both sides accepted Mr. McLeod's compromise proposal to avert the strike—that Mr. McLoughlin should remain on the pay-roll but not enter the factory. No-one among union officials appeared anxious to associate himself with the man's indignant refusal to take " Judas money,"

The court have an opportunity to bring out the facts and expose the roots of the trouble. If they succeed it may please neither the Briggs' shop stewards nor the Ford management. But can they succeed, without months of research? Lord Cameron is likely to find this an even harder nut to crack than the railway dispute two years ago, for this time " relationships," and not " wages," are the main theme.

High Time for Prosperity

The time has come for the Government to relax their restrictive economic policies and for action " to restore growth to the economy." Unless a way is found to make use of " the considerable increase in production capacity which the high level in investment in the past two or three years must have created " unemployment must increase. These are the T.U.C.'s views. They were stated in a letter from the General Council to the Chancellor of the Exchequer.

The T.U.C. and the Federation of British Industries showed similar concern for the tendency of the economy to stand still. Both recommend the restoration of incentives to capital investment. The F.B.I. consider that the volume of investment in 1958 " will almost certainly be less than in 1957 unless some stimulus is given to it; and recommend the restoration of investment allowances. The T.U.C. recommend " larger initial investment allowances to essential industries and services." Both want a relaxation of restrictive measures but in quite opposed directions. Whereas the F.B.I. are for reductions in direct taxation, but against " truly radical reductions," the T.U.C. want reductions in the lower ranges of income tax only and would like to see a capital gains tax. They recommend a reduction in purchase tax on kitchenware and household goods, " to convince trade unionists of the Governments' willingness to reach genuine price stability." They opposed reduced expenditure on social services and supported cuts in defence spending.

Both sides give the impression that they fear disinflation more than inflation, and would take a risk to see production going up once again.

No Safe Dose

Any radiation, however small, is harmful to health, but complete protection is unattainable—at least without losing practically all the considerable benefits radiation has to offer the human race. No one can escape its dangers for " the dose to the individual is only of secondary importance ": it is the total dose to millions of people which counts. These somewhat disturbing statements were made at a symposium on radiation hazards in New York by two of America's leading scientists: Dr. Lauriston S. Taylor of the National Bureau of Standards, and Dr. James F. Crow, Professor of Genetics at the University of Wisconsin.

Dr. Crow stated most emphatically that no dose of radiation is too low to cause genetic effects: " The most frequent cause of mutation is that causing a minor change for the worse—a decreased life expectancy, increased susceptibility to disease, and so on. A mutant which causes a small amount of harm to the individual may do just as much harm to the population as one causing a greater harm." How then is humanity to be protected from so great a danger? Dr. Lauriston Taylor disclosed that the N.B.S's national committee on radiation had recommended the adoption of a new standard reducing by one-third the " maximum permissible dose " of radiation to which individuals should be exposed. This safeguards the individual but, as he and Dr. Crow pointed out, not the future generations.

The Americans are tackling this problem with a commendable sense of urgency and with greater realism than shown so far in this country. The choice between the benefits of nuclear energy and future health may have to be faced sooner than is generally realised. Dr. Taylor could hardly have been more explicit when he said that the new recommendations were probably the lowest practicable: " It will be extremely difficult to lower them any further and still permit the effective use of radiation in medicine, industry or research."

Restive Railwaymen

The claim for a 10 per cent. wage increase put forward by the National Union of Railwaymen was vigorously opposed by the British Transport Commission last week in a statement made to the Railway Staff National Tribunal. Mr. A. B. B. Valentine, a member of the B.T.C., said that such a claim could only be warranted if there had been a " dramatic and substantial change " since the last railway wages settlement a year ago. Of this, he could see no evidence; the rise in prices was only about 4 per cent. No useful comparison could be made with wages paid in other industries because there were too many important differences in the conditions of employment. He instanced working hours, extra earnings, the value of clothing and free travel and that of sickness and pension schemes. In his opinion the rates of pay in the industry were not the cause of the shortage in labour, which was general and nation-wide. In any event, the railways were still " in the red " and had nothing to distribute.

The reply of the N.U.R's general secretary, Mr. J. Campbell, was highly indignant. To wait five years before the workers could hope to benefit from modernisation was, in his view, unrealistic. The improvement in their position vis-à-vis workers in other industries must be gradual, at least in step with the improvement in productivity. Otherwise there could be no hope of a concerted effort on the part of workers and management to put the railways " in the black."

The logic of Mr. Campbell's statement is hard to see. Some part of the improvement in productivity—so far probably the major part—must be attributed to the B.T.C's investment in new plant and equipment, all of which has to be paid for. But Mr. Valentine's statement concerning the Commission's ability to recruit their full needs may not apply universally. In the highly skilled occupations—engine driver, for example—the shortage may be due more to the poor prospects than to any other factor.

Emigration New Style

Style and Italy are fast becoming synonymous. Apart from being the designers of half the world's cars and of most of what is new and elegant in glass, pottery, fabrics, etc., the Italians are making their mark in the post-war design for living. Most of us know of their film stars but few will have heard this story about two parcels wrapped up in glazed cloth found under the seat of a second class carriage in a train bound for Switzerland. On their round of inspection, Italian customs officials noticed the parcels and, as they were unclaimed, opened them. Inside were two peasants from Agrigento in Sicily, who said they were parcelled up by relatives and put on the train at the Milan station. They were duly dispatched, unwrapped, to their home town.

Both were men who had been unable to obtain a permit to emigrate to Switzerland and both unemployed. It could have been, of course, that the relatives' contribution to their fares stopped at the parcel rate. More likely perhaps, is this uncanny sense of the original most Italians seem to possess, coupled with a deep love for the unconventional, whence all may spring.